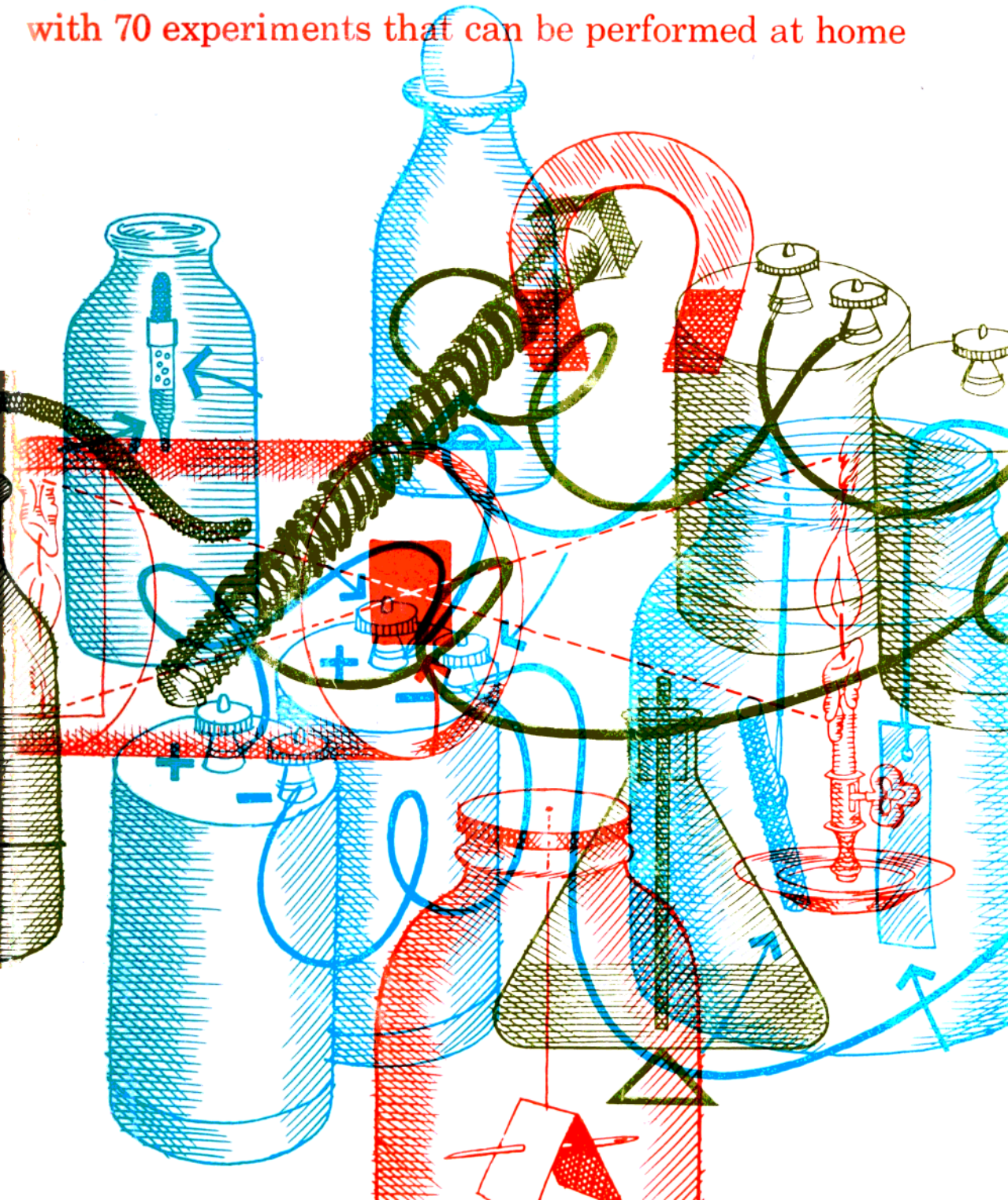
BY DR. STEVEN J. MARK *Illustrated by Charles Wilton*

A PHYSICS Lab of Your Own

with 70 experiments that can be performed at home



$3.00

A PHYSICS LAB *of Your Own*

by Dr. Steven J. Mark

Illustrated by Charles Wilton

The seventy experiments in this book have been carefully selected and arranged to form a step-by-step approach to learning the basic elements of physics. Though they are interesting and often amusing to perform, they are of far more significance than just a collection of experiments that are easy and fun to do.

Beginning with the principles of heat, sound, and light and a study of gases, liquids, and solids, Professor Mark leads the young physicist through an ingenious and relatively simple series of experiments in static and current electricity, magnetism, electromagnetism, and atomic energy, ending with the construction of a working radioactive fallout meter.

Almost all the materials needed for these experiments are readily obtainable in most households or at the corner drugstore or hardware store. The directions are simple and clearly visualized in the many illustrations.

For any child with a scientific bent, this book will provide a firm foundation of laboratory techniques and methods. At the same time, it will show him in terms that he can see, control and understand, just how the laws of physics operate.

Ages 10–12

Dr. Steven J. Mark attended Oberlin College and was graduated from there in 1938. He received his M.A. in physical sciences and science education from Ohio State University in 1944 and his Ed.D. in science education from Pennsylvania State in 1958. Previous to his appointment in 1957 as professor in science education at Kent State University, Dr. Mark was a teacher and supervisor of elementary and junior high school sciences in the Lorain, Ohio, Public School System, and supervisor of chemistry and physics at Kent State University School.

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A PHYSICS Lab of Your Own

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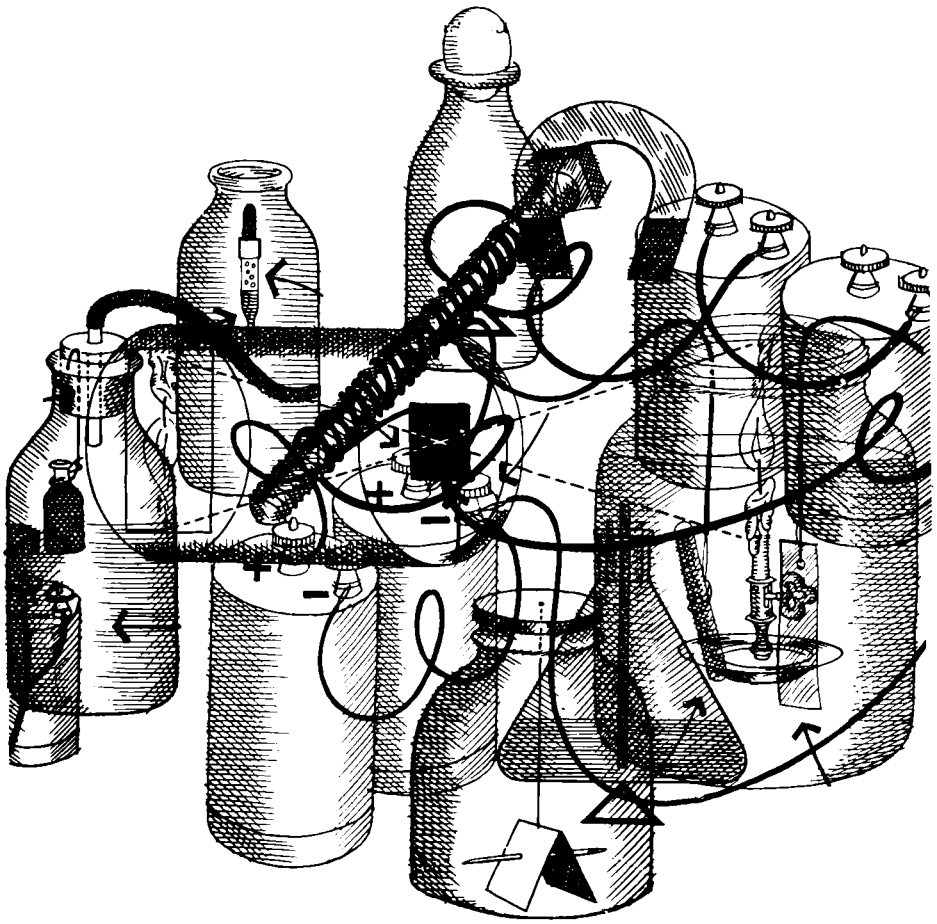
DR. STEVEN J. MARK



Illustrated by Charles Wilton

HOUGHTON MIFFLIN COMPANY BOSTON 1964

The Riverside Press Cambridge

To my sons and daughter

JANIS, DON, and GENE

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1

INTRODUCTION

WHAT IS PHYSICS?

When you try holding a glass of water upside down with only a screen over the mouth of the glass, or when you make a tin-can telephone, you're learning something about physics. When you crush a gasoline can with air pressure, or make an electric motor or a radiation detector, you're also learning about physics.

For physics is the study of energy and what energy can do to matter. Physics is one of the most basic of all the sciences, and at the same time one of the most exciting, for physicists today are the men and women who are unlocking the secrets of the atom, who are reaching into outer space to solve the mysteries of light, electricity, and magnetism.

You don't need a lot of fancy and expensive equipment to start a physics laboratory of your own. This book shows you how you can set one up and how you can perform a series of experiments, like the ones mentioned above, that will take you into every area of physics. You won't be making any new discoveries, of course, but you'll be starting out just the way any other scientist does, actually setting up equipment, observing the results of your experiments, and understanding the

principles behind the experiments.

How do physicists work?

When you were learning to roller-skate or ice-skate, did you start off rapidly and full of confidence the very first time you put on skates? Were you successful on the first attempt? Of course not. Most likely you were even ready to call it quits after several thuds. All of us have had these and similar experiences. We did not call it quits. Instead we got back on our feet and tried again, and again. We observed others who were more graceful because of experience. We learned by observing them. Some of us may even have gone to the library to read up on skating. Although we did not realize it, we were experimenting.

Physicists, like other scientists, learn new things by *reading*, *experimenting*, *observing*, and *drawing conclusions*. This is what we shall do.

Don't become discouraged if some of the experiments fail to work on the first attempt. Just reread the experiment and try again. Outstanding scientists have spent millions of dollars and thousands of hours doing research in such fields as agriculture, space travel, medicine, and in many other areas. They haven't found answers for all their problems. But they keep on experimenting.

Where do we use physics?

During every step you and I take, we are moving some form of matter — our bodies and our clothing. In order to move these substances, we must have energy. The food we eat and drink is the source of this energy.

The food we had for breakfast or lunch was produced with the help of many principles of physics. Principles of heat, light, electricity, friction, and communication made it possible for this food to grow, to be prepared for the table, and to be shipped to stores and our homes.

Our jets, rockets, radar, color television, telephone, and space missiles have been made possible through the work of physicists.

It is not common for us to think that physics is used in playing tennis, in swimming, dancing, baseball, and all other sports. But it is.

Doctors, dentists, engineers, and machinists are some of the other people who must understand and use the laws of physics in their work. When you were ill, the physician used principles of sound, light, and temperature to help determine what was wrong with your body. This made it possible for him to help you recover your health. The dentist, likewise, uses principles of physics when he works on your teeth, as do engineers and machinists while building or repairing bridges, machines, highways, skyscrapers, and the like.

What you should consider in setting up your lab

The location and organization of your home laboratory will play an important part in your work with the experiments in this book. Discuss possible locations with your parents or with your teacher. Here are a few points to keep in mind as you plan a place for your laboratory:

1. At home, the utility room, workbench, or a sec-

tion in the basement makes a good place for a physics lab.

2. It should be located where it will not interfere with the activities of other members of the family.

3. There should be plenty of light and fresh air.

4. There should be running water nearby.

5. If you care about the finish on your workbench, it should have a waterproof surface. A piece of oilcloth or a sheet of glass will serve the purpose.

6. There should be a safe electric outlet close at hand.

7. There should be sufficient storage space for chemicals and equipment.

Your lab may look like this:

Why you should buy a notebook

You will get much more pleasure and value out of your physics lab if you keep proper records of what you do and observe during experiments. Buy a notebook and a ball-point pen. In the notebook, write the number of the experiment, state the problem, list any steps you take other than those described in this book, record *your* observations, and list the conclusions *you* make from your observations. This, after all, is what the professional scientists do, and by keeping a notebook yourself you will have a good permanent record of what you have discovered for yourself in the lab.

Challenge yourself by trying to figure out the explanation for each experiment before reading the explanation given in the book. *Then* check your explanation with the one in the book. You may wish to perform the

experiment again to obtain a better knowledge of it; scientists often repeat an experiment many, many times.

Keep your notebook neat and attractive. Occasionally show it to your parents and your teacher. Let each page represent your very best efforts. You may want to add clippings, photographs, specimens, and other items to enrich your reports.

How the experiments are presented

Let us consider a situation that shows how we may use experiments to help us solve problems.

Two boys in a science class could not agree on whether the temperature of ice water was raised or lowered when salt was sprinkled over the floating ice cubes. One boy insisted that the temperature was raised because after the salt was sprinkled over the ice, the ice began to melt faster. The other boy maintained that the temperature of the ice water was lowered because the melting ice took heat from the water. They soon learned that they could not settle the problem by shouting and arguing. So they tried to find the answer in books. They were not successful. Next they consulted their science teacher, who gave them some help but did not solve their problem. Finally, one of the boys suggested they perform an experiment.

These are the steps they followed:

First, they studied the *problem* that faced them. They agreed to state it this way: Will the temperature of ice water rise, fall, or stay unchanged when salt is sprinkled into it?

Second, after they studied the problem, they collected some of the *materials* that they felt were needed for the experiment. The boys decided they needed a thermometer, ice cubes, salt, and a soup dish.

Third, they decided on the possible *steps* to take in performing the experiment. They decided to set up the experiment; sprinkle salt over the top of the ice; make observations; take several readings of the thermometer; and draw conclusions based on their findings.

The boys observed that the temperature of the salt water dropped after the salt was sprinkled over the ice but were unable to understand why ice should melt with a drop in temperature. They needed one more step to complete their experiment. They needed an *explanation*. Can you explain it? How would you go about it?

Fourth, as you have probably guessed, the explanation here has to do with the fact that a solution of salt and water has a lower freezing point than does water alone. So it's not the drop in temperature that in itself causes melting but the fact that 32°F no longer represents a freezing point for the solution. Depending upon the amount of salt in the water, the freezing point for the solution can be as low as 22°F.

The experiments presented in this book are organized in the same order the boys used in solving their problem.

1. An understanding of the problem.

2. Listing the materials needed for the experiment.

3. Steps or procedures necessary to work out the problem.

4. An explanation of the experiment.

Some of the things you will need for your experiments

Whether you want to repair a bike or make a frosting for a cake, you need certain kinds of tools. Although you may not have the exact tools for the job, you can usually make do somehow with what is at hand. This is also true when experimenting with physics.

Many of the items listed can be found in the garage or kitchen; others can be purchased from a store that sells science apparatus. Check your phone directory to find out if such a store is located in your city.

2 household thermometers (Fahrenheit) — hardware or dime store

2 candles, about 6 inches — dime store

2 shallow soup dishes

4 dry cells — hardware store

5 balloons

1 old toothbrush

2 horseshoe magnets — science supply house

1 magnetic compass — hardware store

2 medicine droppers

6 pop bottles

4 paper cups

2 cylindrical cereal boxes

4 small cans from concentrated fruit juices

1 screwdriver

1 pair of pliers

1 jackknife

1 light bulb, 100W

1 yardstick

10 soda straws

1 roll of cellulose tape (for example, Scotch tape)

1 measuring cup

1 spring balance (0–28 oz.) — science supply house or hardware store

1 pair of scissors

1 triangular file — hardware store

1 metal gallon can

3 ft. of 6-mm. glass tubing — science supply house

6 Pyrex test tubes (about 20 ml. volume) — science supply house

4 oz. mercury — science supply house

1 heat source, hot plate preferred — hardware store

1 electric doorbell or buzzer — hardware store

1 salt shaker

4 screw-base flashlight bulbs — dime store

4 sockets for flashlight bulbs

4 small porcelain or round metal switches — hardware store

5 ft. No. 20 (small diameter) copper wire — hardware store

assortment of corks

spoons

empty cigar boxes for containers
salt
vinegar
baking soda
pieces of zinc, from old dry cells
knitting needles
forceps
small glass mirror
rubber bands
ball of string
large steel bolt
piece of fine sandpaper
quart-size glass milk bottle

Here are a few science companies that sell science supplies of various types:

Central Scientific Co.
1700 Irving Park Rd.
Chicago 13, Ill.

Chemical Rubber Co.
2310 Superior Ave.
Cleveland 14, Ohio

Fisher Scientific Co.
711 Forbes Ave.
Pittsburgh 19, Pa.

Michigan Scientific Co.
6780 Jackson Ave.
Ann Arbor, Mich.

W. M. Welch Scientific Co.
1515 Sedgwick St.
Chicago 10, Ill.

United Scientific Co.
200 North Jefferson
Chicago 6, Ill.

You may want to look at some of the catalogs of these companies in the science laboratory of your local high school. Of course, be sure you get permission from the teacher concerned. The science teacher will be glad to answer questions you may have about the various science supplies.

2

GASES, LIQUIDS, SOLIDS

The three states of matter

It may be difficult for us to believe that everything — actually everything from an ice cube to a star — in this universe can be placed in just one of these simple groups or classes. They are gases, liquids, and solids. Each group has its own peculiarities. Each occupies space, however, has weight, and is composed of millions of particles. Scientists refer to these three groups as the three states, or forms, of matter.

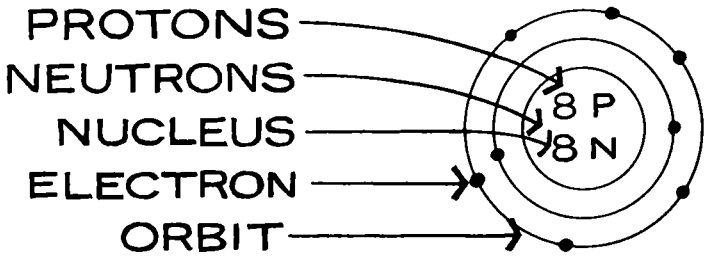
We have made use of each form of matter many times today and will continue to do so in the future. Every time we pick up a piece of chalk, a slice of bread, or a candy bar, we are handling a solid. The water, milk, or pop we drank today is an example of a liquid. The air we inhale is composed of oxygen, nitrogen, and carbon dioxide. These are the common gases found in the air.

The make-up of all matter — gases, liquids, solids

All matter, whether a tiny speck of gold or a huge mountain, is composed of particles. In many cases these particles are atoms. Even our bodies are made up of atoms. These basic building blocks are far too small to

see, even under the most powerful microscopes. But atoms themselves are not "solid matter" either. They were once thought to be something like a tiny solar system that is mostly empty space, and this is still a useful way to picture an atom. In the center, where the "sun" would be, is the nucleus. This is made up of particles called protons and neutrons. The protons carry a positive electric charge, and the neutrons carry no charge at all. You might say they are neutral.

Traveling around the nucleus are negatively charged particles called electrons. The kind of an atom depends on how many electrons are located around the nucleus. For example, hydrogen has one electron, carbon has 6, gold 79, and uranium 92. All together, there are 103 different kinds of atoms which form 103 different elements. Examples of some of the more common elements are hydrogen, oxygen, nitrogen, carbon, gold, silver, radium, uranium, mercury, lead, iron, aluminum, and zinc. The following is a diagram of one of the 103 elements, namely, oxygen:



In most cases, the matter we see around us is composed of different kinds of atoms that are joined in the form of molecules. If matter is made of only one kind

of atoms, it is called an element, but if there are two or more different kinds of atoms, it is called a compound. Common table salt, for example, is composed of a sodium atom joined to a chlorine atom, while water is composed of two atoms of hydrogen hooked onto one atom of oxygen. Some molecules that make up animals and plants are tremendously long chains of atoms of carbon, oxygen, and hydrogen.

In the experiments that follow, we won't be able actually to see the atoms or the molecules, but we shall be able to study their effects and thereby learn more about them. In this respect we shall be no different from the most advanced physicist in the world, for no scientist has actually seen any atoms. All that we have learned about them has been gained by studying their clues or their behavior.

Properties of solids, liquids, and gases

Take an ice cube and squeeze it between the palms of your hands. What happens? Allow the entire ice cube to melt in a small dish. Then heat the dish with its contents. Observe what happens to the water. Here we have an illustration of a compound that can exist in three different forms at different times. Yet, whether it is ice (solid), water (liquid), or water vapor (gas), the substance is composed of identically the same two atoms of hydrogen and one atom of oxygen — H_2O. What are the differences between the various states of matter? Let us examine each.

Properties of gases

In the sciences the best way to describe a substance is to list its "properties." If you were asked to give the properties of sugar, for example, you could say that it is a white solid, will dissolve in water, tastes sweet, turns black after being heated, and is composed of carbon, hydrogen, and oxygen. We can list properties of gases in a similar way.

Gases occupy space and have weight. We know this to be a fact, for on numerous occasions we inflated a tire and found it to be heavier than when it was deflated.

Air can be forced into a balloon or a glass bottle because there are spaces between gas molecules. Forcing gases into such containers pushes the molecules closer together. We say that gases can be compressed.

A basketball remains inflated because the gas molecules are continuously bombarding the inner walls of the ball. These molecules are traveling at a terrific speed — faster than you and I can run.

Another important property of gases is that they are soluble in many liquids. Our water would taste flat were it not for the dissolved air in it. Fish would die were it not for the dissolved oxygen in the water.

Properties of liquids

We can run with ease through air. But have you tried running through water while in swimming? If you have, you have learned that you can make better progress through air than through water. The mole-

cules in liquids are closer together than those in gases. Molecules in liquids also have greater attraction for each other than those in gases. Consequently, they offer greater resistance to any substance that attempts to separate them. The resistance at the surface is sufficiently strong to enable small insects, grains of sand, some other liquids, and even needles to float on top of the water. This attraction of water molecules for their neighbors at the surface of the liquid is called surface tension.

Another important property of liquids is that they take the shape of their container. You can see this for yourself if you pour water into containers of different shapes. You may want to fill an irregularly shaped flower vase or a teakettle. You will notice that the liquid takes the general shape of the container. This is not necessarily true of solids and gases.

Liquids, like the two other forms of matter, exert pressure on the containers in which they are kept, and also on any object that may be placed in them. Deep-sea divers can go only so deep without special equipment. The pressure on one square foot of your body immersed in fresh water to a depth of one foot is 62.4 pounds. At a depth of 10 feet the pressure would be 624 pounds per square foot. From this we can see that if a diver went below a specified depth without special equipment, the water pressure would be great enough to crush him. Can you see now why some deep-sea animals may "explode" if brought to the surface too quickly?

Of course, all liquids do not feel wet, nor are they all watery. Mercury, a silver-colored element, does not wet most objects that it touches. Honey, molasses, oil, and tar are also liquids, but they are not as free-flowing as water.

Properties of solids

In general, the atoms of a solid are packed together much more closely than those of either gases or liquids. If it is harder to run through water than through air, imagine what it would be like to try to run through a brick wall!

What else do we know about solids? Some, like sugar and salt, will dissolve in water; others, like iron and marble, will dissolve in acids; and some, like gold, are very hard to dissolve in anything. Some solids bend (like a copper wire) and some break (like a china plate). Some are hard and some are soft.

Some solids (like metals) melt and turn into liquids, and the liquids eventually become gases if you get them hot enough, while others, instead of melting, burst into flame before they melt. Imagine, for example, trying to melt a piece of wood. All solids do not burn or melt at the same temperature. We can start paper burning with a lighted match, but it is necessary to have the temperature of a blast furnace to melt iron ore — temperature between 2500 and 3000 degrees Fahrenheit.

Each solid substance, as well as gaseous or liquid substances, has its own density. This means that a quart of feathers does not weigh the same as a quart of iron.

Density is commonly expressed as the weight of the substance in pounds per cubic foot. The densities of a few common materials are as follows:

cork	15 lb. per cu. ft.
paraffin	56 " " " "
aluminum	165 " " " "
iron	470 " " " "
mercury	849 " " " "
gold	1200 " " " "

These densities play a vital role in determining the size and shape of the ships that carry astronauts into space.

Now let us study the many properties of solids, liquids, and gases by performing the following experiments.

Experiment 1 Air occupies space

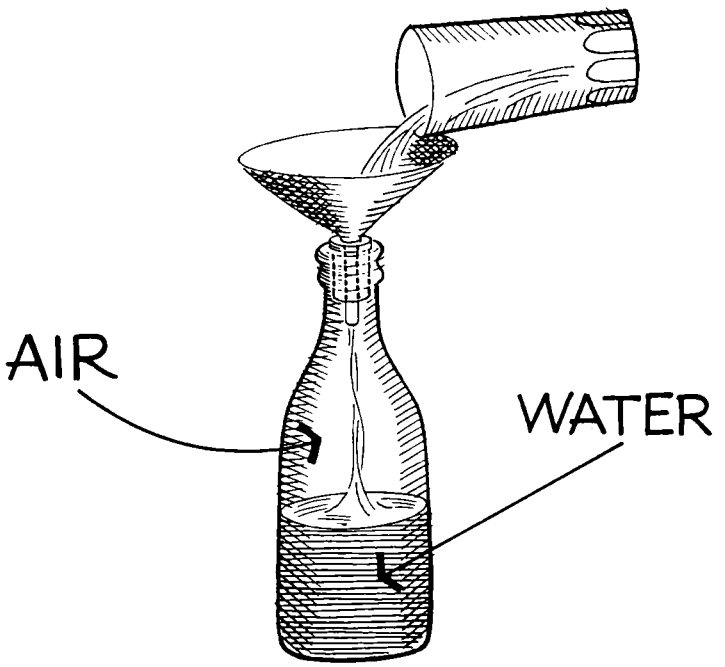
Take a large pan or jar and put your hand inside. Do you feel anything? Now invert the jar. Do you see anything fall out? Your answer in both cases, most likely, is "no" (unless you have forgotten to empty the jar!). In terms of your actual observations, this is the best answer you can give. The container, however, is not actually empty. It is filled with air even though we cannot see it. It can be easily shown that air does occupy space by performing this experiment.

Materials: A funnel, a bottle, a one-hole stopper to fit the bottle (the stem of the funnel projects through the hole), and a water glass.

Procedures: Set up the experiment as shown below.

1. Lubricate the stem of the funnel with a few drops of water or soap before pushing it through the hole in the stopper. Use a gentle twisting motion.
2. Push the stopper with the funnel firmly into the mouth of the bottle.
3. Pour water from the glass into the funnel.
4. When no more water will flow into the bottle, stop pouring the water. Observe the spurting action.
5. After a few minutes, loosen the stopper and hold it above the neck of the bottle. Pour more water through the funnel into the bottle. Repeat several times.

Explanation: The bottle is full of air at the beginning of the experiment even though we are unable to see or



feel it. At the beginning, some water flows in because *air can be compressed.* Later, water will flow in only if some air is allowed to escape. The spurting of water is caused by the escaping air. When the pressure of the air in the bottle is greater than the pressure of the water in the funnel, the air rushes out in spurts. Some water now rushes in to replace the air. This process is repeated until the air pressure in the bottle is equal to the water pressure in the funnel plus the pressure of the atmosphere above the funnel.

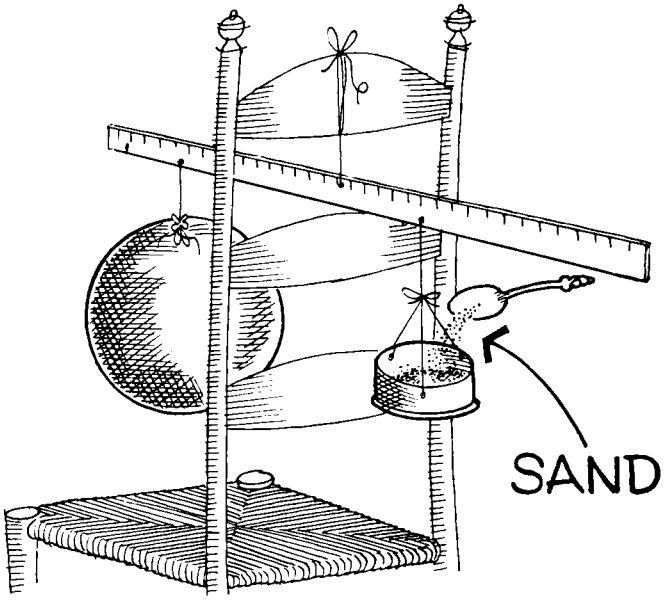
Experiment 2 Air has weight

It is hard to realize that a material which you cannot see or feel, under normal conditions, weighs something. But you can show that air actually does have weight by performing Experiments 2 and 3.

Materials: A yardstick with small holes at the 6-, 18-, and 24-inch marks, a beach ball or large balloon filled with air, a shallow can (tuna can), sand, a spoon, and some string.

Procedures:

1. Suspend the yardstick by a string attached to the middle hole. You may want to use a window sill, the end of a table, or a rung on a tall chair.
2. Suspend the inflated ball from the 6-inch hole.
3. Hang the small can from the 24-inch hole, as shown in the diagram. If the empty can weighs more than the balloon, hang it closer to the center.



4. Using a teaspoon, fill the can with sand until it just balances the inflated ball.

5. *Carefully* release all the air from the ball. Watch that the sand does not spill over your lab.

Explanation: When the yardstick is balanced, the weight on the left is equal to the weight on the right. As the air leaves the ball, the left side of the stick goes up and the can goes down. Since air has left the ball, the ball becomes lighter. This shows that *air has weight.*

It is even possible to weigh the amount of air that was in the inflated ball or balloon. This you may do by balancing the yardstick with the ball empty. Next, blow into the ball and return it to the yardstick. Add sand until the stick balances again. The amount of sand you add shows you the weight of the air. Of course, the amount of sand added will be very small because air is very light. One gallon of air weighs a little more than 1/7 of an ounce, or about the weight of a five-cent piece.

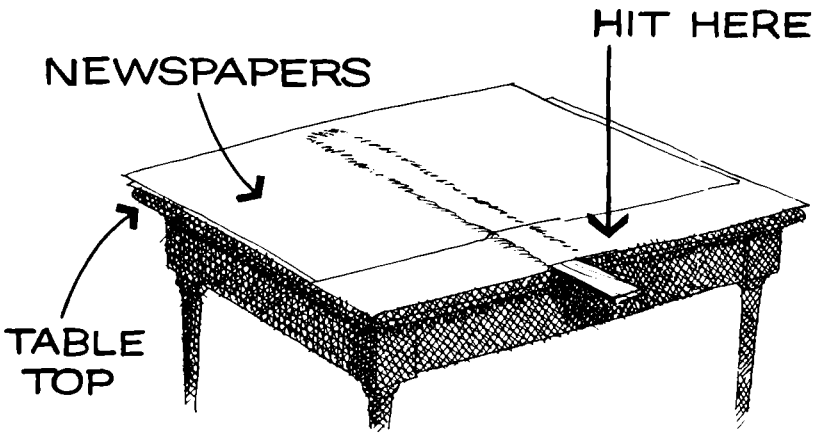
Experiment 3 Using an "air clamp" to break a slab of wood

Here is another experiment you can do to show that air has weight.

Materials: Two sheets of newspaper without holes or tears, a stick from an orange crate about 1″ x 24″ x ⅛″, and a foot ruler or a small hammer.

Procedures:

1. Place the stick on the table so that only about 4 inches of it projects over the edge.
2. Spread open the sheets of newspaper and smooth them out over the stick and the table. Be sure that all the air is out from under the paper.
3. Consider the safety of your visitors and the windows before performing this part of the experiment. Give the outer end of the stick a sharp blow with the ruler or the hammer.



Explanation: The stick breaks at the point where it is touching the edge of the table. The stick breaks here because the part on the table is held by the weight of the air on the sheets of paper. The total force of the air pushing down on the newspapers is tremendous. The force in pounds can be calculated by finding the area of the newspaper and multiplying it by 14.7 pounds, the force per square inch, as follows: 31 in. x 23 in. = 713 sq. in. (area of newspaper); 713 sq. in. x 14.7 lb. per sq. in. = 10,500 lb.! These thousands of pounds of air exert sufficient force on the paper to make it possible to break the stick. (Do not use a stick that is too thick.)

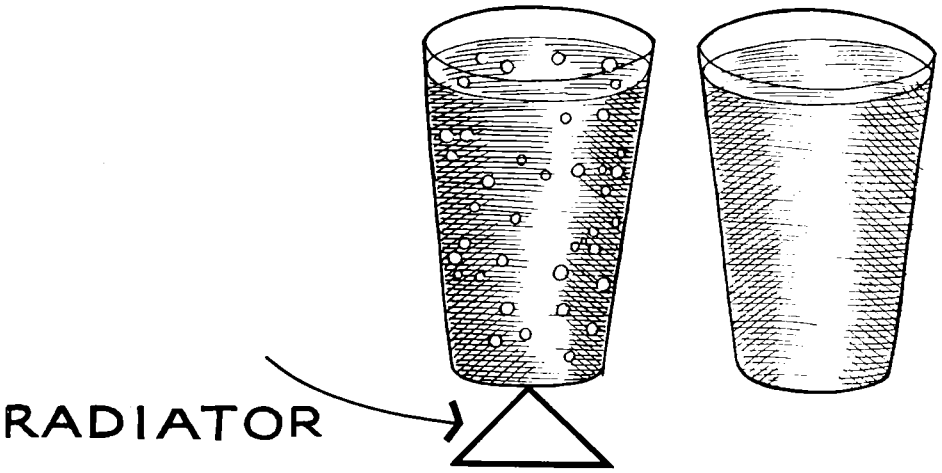
Experiment 4 "Squeezing" water out of air, and air out of water

No doubt you have wondered why a glass of water that is allowed to stand in a room will have air bubbles on the inside of the glass. You may also have noticed that a *dry* bottle taken from a refrigerator will feel damp after it has stood on the table for a few minutes. Let us find out what happens in each case.

Materials: Two thin water glasses and a bottle of pop or milk that has been in the refrigerator.

Procedures:

1. Take a cold bottle from the refrigerator and let it stand in a warm room for several minutes. Now feel



the outside of the bottle. From where did the moisture come?

2. Fill each glass with *cold* water from the faucet.

3. Place one in a warm part of the room and allow it to stay there for a few minutes. Place the other above a *warm* radiator or in bright sunlight for a few minutes. Careful observation will reveal that though both glasses feel damp on the outside, the glass on the radiator will also have air bubbles adhering to it on the inside.

Explanation: Let us answer the first part of our experiment, namely: Why can we "squeeze" water out of air? Warm air can hold more water vapor than cold air, which is why you can have hot muggy days, but not cold muggy days. A cold container cools the air next to it. As a result, the air surrenders its water, which then settles on the cold surface. This is why windows "steam up" on the inside when it is cold outside, and why a cold bottle or can collects moisture in a warm room.

Now for the bubbles in the glass on the radiator: Cold water as it comes from the faucet has gases dis-

solved in it. Most of the gas dissolved in faucet water is air — chiefly a mixture of nitrogen, oxygen, and carbon dioxide. We are unable to see the air molecules because they are so small and are dissolved evenly throughout the water. Warm water holds less dissolved air than cold water. This is so because the heat causes the gas to expand more than the water. The gas molecules then work their way out from among the water molecules in the form of gas bubbles. Some of the bubbles may settle momentarily on the glass wall on the inside. Do you see why an aquarium should not be kept in too warm a place? Remember, fish need air (oxygen) for life.

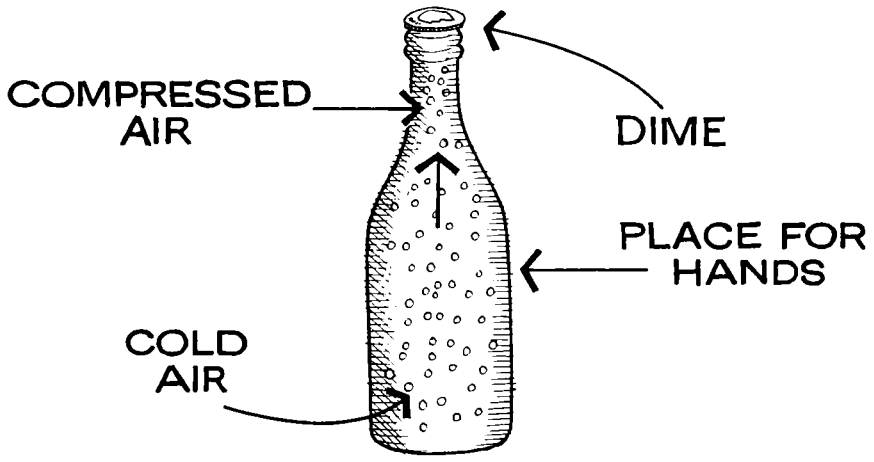
Experiment 5 Making a dime dance

Up to this point, we have seen, through experiments, that air has weight, occupies space, and can dissolve in water. Air can also do work. Several experiments will convince you of this, though some of them seem to have a touch of magic.

Materials: An empty pop bottle and a dime.

Procedures:

1. Either rinse the bottle with *cold* water or set it in a refrigerator for about ten minutes before using it. Take the cooled bottle, moisten the rim, in order to form a seal, and place a dime on the rim. Be sure the dime covers the *entire* rim, and there are no chips on the rim.
2. Hold your hands around the lower part of the bottle



for a few minutes. The experiment works best when your hands are warm.

3. Observe what happens as you place your hands around the bottle repeatedly.

Explanation: A cooled bottle is used in order to have a large supply of air in it. Cold air is denser than warm air. When your hands are around the bottle, the air inside is heated. The heated air expands, thus increasing the pressure inside the bottle. The escaping air lifts the dime. Each time some of the air escapes, the pressure in the bottle is decreased and the dime falls back onto the rim. This action will continue as long as the air in the bottle is cooler than the temperature of your hands.

Experiment 6 Putting an unbroken egg into a milk bottle

Give your friend a hard-boiled egg with the shell off, and a glass quart milk bottle. The egg should be just a little larger in diameter than the top opening of the

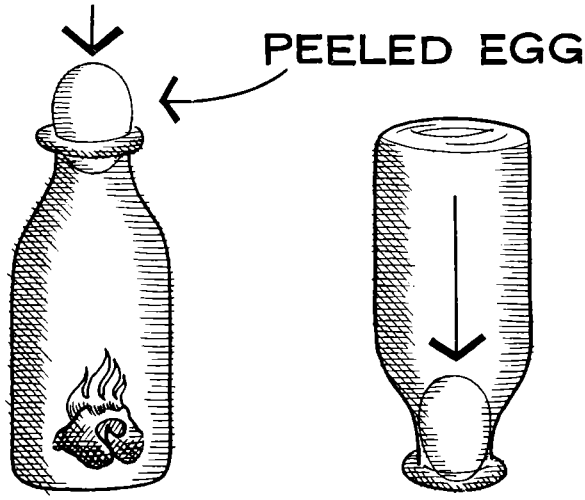
bottle so it won't just fall in. Ask your friend to put the egg into the bottle without using any tools and without touching it after it has been put on the top of the bottle. If he fails to do it, you can show him how simple it is.

Materials: A dry glass quart milk bottle, a hard-boiled egg, a wad of paper, and a match.

Procedures:

1. Into the dry milk bottle drop a large burning match or a wad of burning paper.
2. Place the egg, with the narrower end in the bottle, on top of the bottle just before the flame goes out. Observe what happens.
3. To remove the egg is just as tricky. Invert the bottle and have the narrow end of the egg in the opening. Blow into the bottle as hard as you can. Stop blowing suddenly, thus allowing the egg to fill the opening. It may help to place warm hands around the bottle. (Then, if you're hungry, you can eat the egg.)

Explanation: The burning material heats the air and



causes some of it to escape. After the flame goes out, the air in the bottle starts to cool and contract. The pressure inside the bottle becomes less than the atmospheric pressure. The atmospheric pressure pushes the egg into the bottle.

The egg is pushed out of the bottle because the air pressure inside is greater than the atmospheric pressure on the outside.

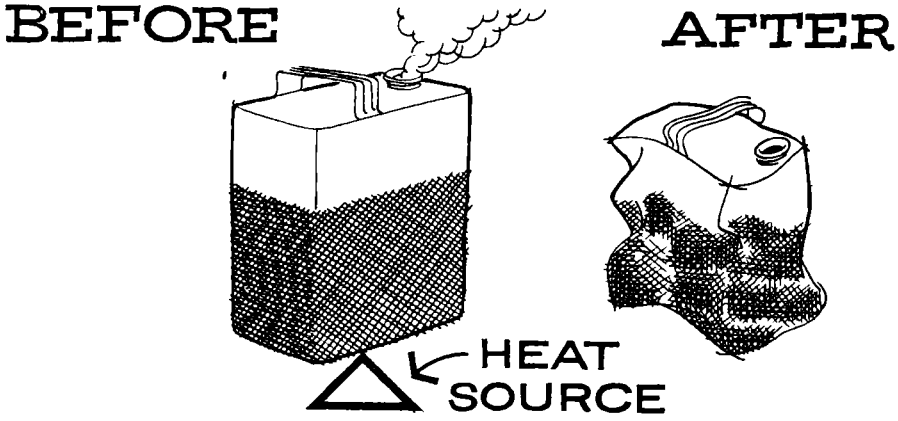
Experiment 7 Using air pressure to crush a metal can

Are you strong enough to crush a metal gallon can by blowing on it? It's easy if you know how. It's more fun if you understand how it is done. Try this experiment.

Materials: A metal gallon can with flat sides and with just one round hole, a stopper or cap to fit this hole, and a hot plate.

Procedures:

1. Pour about ½ cup of water in the can.
2. Heat the can on the hot plate until steam is seen escaping *freely*. Heat for an additional three or four minutes.
3. Using pot holders to protect your hands, remove the can from the heat and *immediately* stopper it *firmly*. A rubber stopper works best. Watch all sides carefully.
4. Blow on the can. Listen. Can you hear the water boil in the can as the temperature continues to drop?



Pouring a glass of cold water on the can gives even more spectacular results.

Explanation: During the heating, the steam forces millions of air molecules out of the can. After the can is stoppered and cooled, the inside pressure becomes less than the outside pressure of the air. This happens because when the steam (gas) changes to water (liquid), the molecules move much closer together and take up less space. The can is crushed by the air pressure outside of the can because it is greater than the pressure on the inside. *The blowing did not crush the can. It merely hastened the cooling process.*

Water in the can may start to boil as the temperature drops. This boiling is caused by the reduced pressure above the water within the can.

Experiment 8 Making a simple barometer

The barometer is an instrument that measures the actual pressure of the air around us. By showing whether the atmospheric pressure is increasing or de-

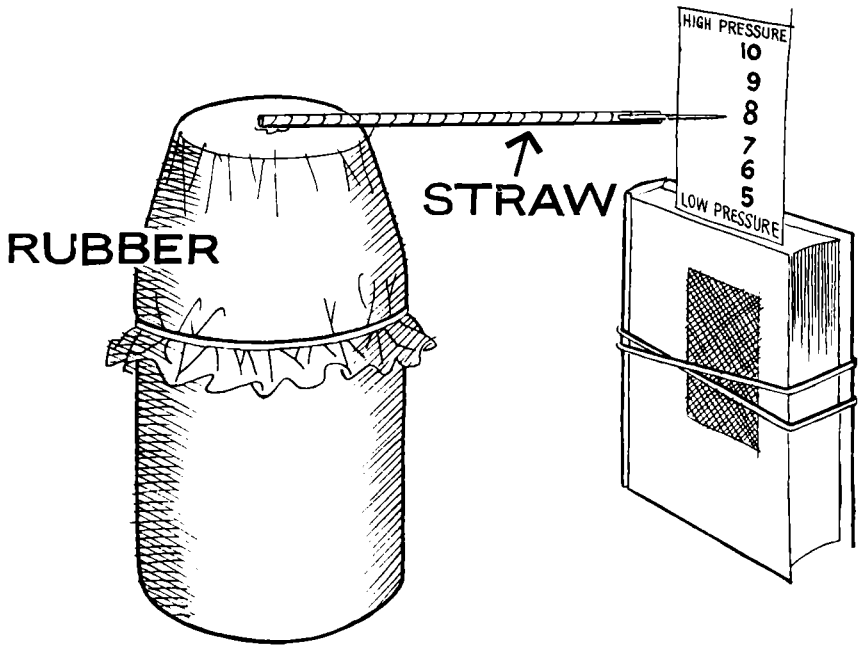
creasing, barometric readings help the weather man to predict changes in weather conditions.

We can make such an instrument from simple household materials. Of course, our instrument will not give us readings as accurate as those obtained by meteorologists, but it does work.

Materials: A balloon, a quart jar, a rubber band, a toothpick, a drinking straw, glue, and a piece of cardboard.

Procedures:

1. Cut the balloon so that you can stretch it across the top of the quart jar. Fasten it with the rubber band.
2. Glue the toothpick to one end of the drinking straw. Use as little glue as possible to keep this part light in weight.
3. Glue the other end of the straw to the balloon as shown in the diagram.
4. Make a simple uniform linear scale on cardboard to which the indicator will point. Fasten it to a book, and



place the bottle with the indicator near it.

5. Record the readings of the pointer on the scale for several days. Compare them with those of the weather man. Since the accuracy of your readings depends on a constant temperature, you should keep your barometer away from radiators and direct sunlight, and out of air drafts.

Explanation: The indicator moves up and down the scale and thus indicates the changes in pressure. When the pressure is high, the pointer goes up; it goes down when the pressure is low.

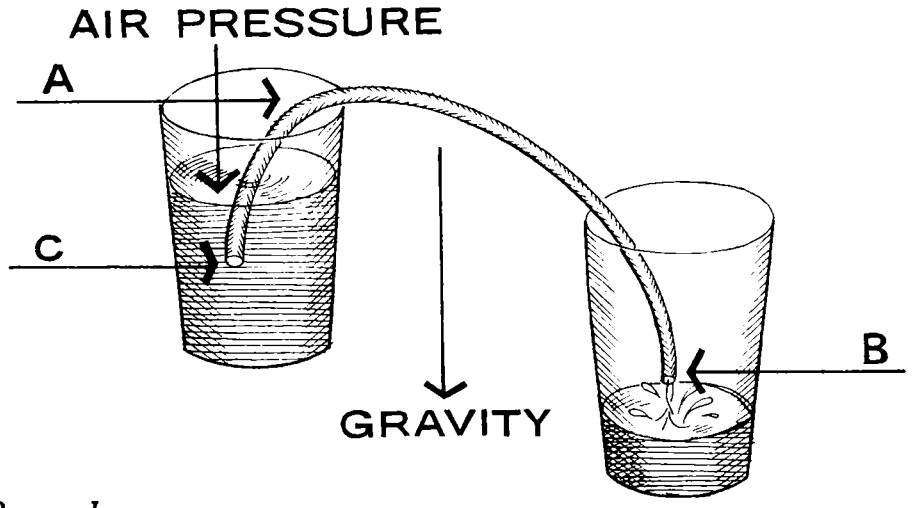
A barometric reading of 29.5 inches means that the atmospheric pressure is great enough to support a column of mercury 29.5 inches high. A reading of 30 inches at sea level is considered average.

Experiment 9 Filling a glass by remote control

All three forms of matter are affected by gravity and pressure. From previous experiments we have seen that pressure is a force exerted by one material upon another. Gravity, on the other hand, is a force by which all bodies attract each other.

The following experiment will show us how gravity and a difference in pressure cause a siphon to work.

Materials: One foot of small-size rubber tubing and two glasses.



Procedures:

1. Fill one of the two glasses with water and place it on the edge of a table.
2. Fill the rubber tubing with water by placing it under the faucet while in a U position.
3. *Squeeze* firmly one end of the tubing with your fingers, and place the other end in the beaker or glass of water. The glass into which the water flows must be lower than the one containing the original water.
4. Release your grip on the tube. Change the heights of the glasses alternately.

Explanation: The water will flow from the full glass to the empty glass until the levels are the same in both.

The rubber tube is filled with water to drive out the air. The water in arm AB weighs more than the water in arm AC. Gravity pulls with a greater force on AB than on AC. The atmospheric pressure above the surface of the water in the glass with the greater height pushes more water up into the tube.

Air pressure and gravity make a siphon possible.

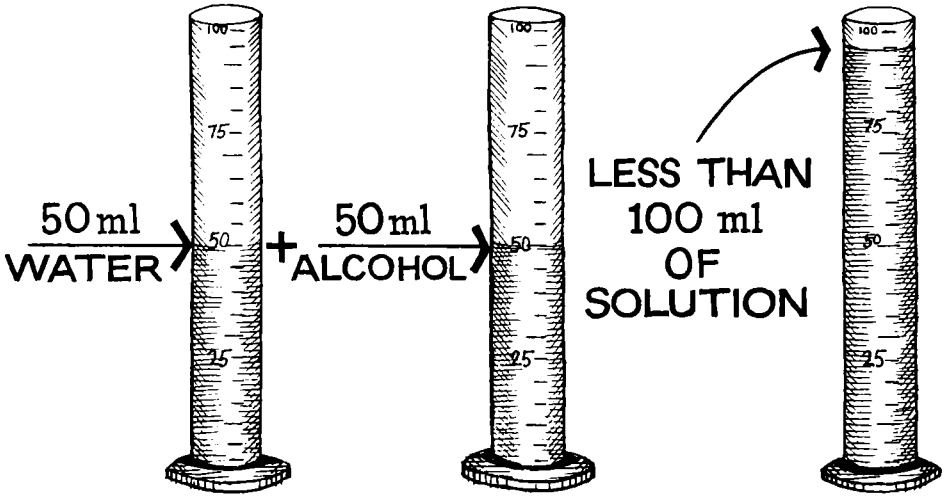
Experiment 10 How do liquids mix?

We have learned that 50 + 50 = 100. Would you believe that there are times when 50 + 50 = only about 95? This can be shown to be a fact by doing the following experiment.

Materials: A 50-ml. graduated cylinder, a 100-ml. graduated cylinder, and a good grade of rubbing alcohol.

Procedures:

1. Measure exactly 50 ml. of water in the 100-ml. graduated cylinder.
2. Measure exactly 50 ml. of alcohol in the 50-ml. graduated cylinder.
3. Add the 50 ml. of alcohol to the 50 ml. of water in the larger cylinder.
4. Mix the two liquids by rotating the cylinder *in the palm* of your hand. Be careful not to lose any of the solution.
5. Allow the solution to stand for a few minutes. You may want to cover the top with a piece of paper to prevent evaporation.



6. Record the combined volume in your lab book. Read the lowest part of the concave curve.

Explanation: The new volume will be less than 100 ml. It will read between 94 and 96 ml. This shows that there are spaces between the molecules of any substance. Apparently the smaller molecules of water work their way into the spaces between the larger molecules of alcohol.

Experiment 11 How do liquids hold together?

Carefully place a needle on the top of water in a shallow dish. (You may want to lay a piece of tissue on water and then rest the needle on it. With care remove the tissue.) The needle floats because the water molecules hang on to each other to form a skinlike layer at the surface. The force of this layer is called surface tension — a property of liquids. If you look at a drop of water that has been placed on a piece of waxed paper, you can see that it has definite "edges" that keep it within bounds. Surface tension keeps the water drops from flattening out.

Surface tension has considerable force. It is strong enough to support small insects while they skim over the surface of the water. It contributes to the reddened skin which you get when you hit the water if you happen to do a "belly-flop" dive. Likewise, it is surface tension that makes it possible to fill a glass beyond the rim with water.

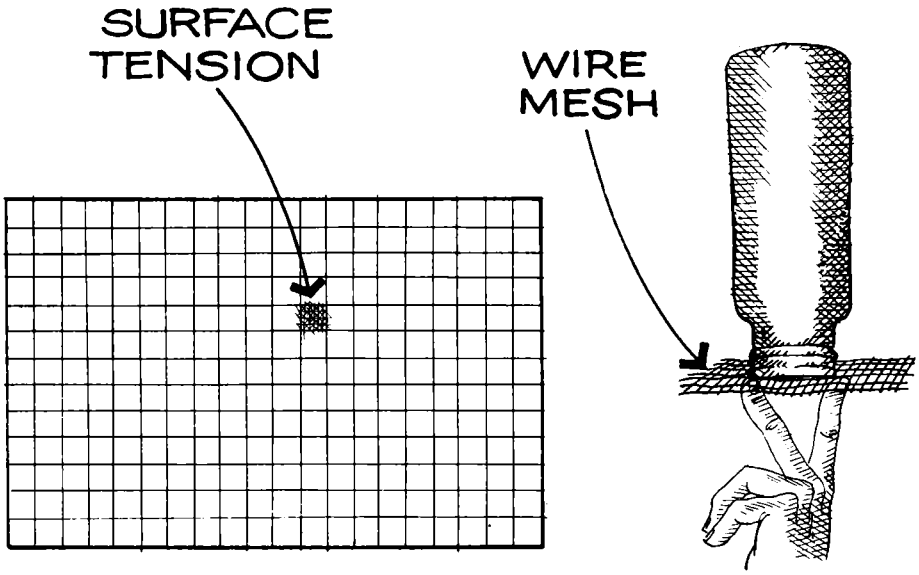
Let us see how *we can carry water in a sieve* with the aid of surface tension.

Materials: A tall bottle and a 4″ x 4″ piece of very fine window screen.

Procedures:

1. Fill the bottle with water, and place the screen over the mouth of the bottle. Be sure the screen makes a good contact with the rim of the bottle and that there are no uneven spots around the rim.
2. Invert the bottle, using the palm of your hand as a source of support. Gradually remove the palm of your hand in such a way that only two fingers support the screen. Better perform this experiment over a sink or a large pan!

Explanation: The wire screen, having very fine holes, causes the water in each hole to have a strong surface tension — "water skin." This prevents the water from pouring out of the bottle. The total surface tension on the screen is greater than the force of the water push-



ing on the screen. Furthermore, the surface tension forms a wall on which the air pressure pushes from underneath. The upward force of the air underneath is greater than the downward force of the water in the glass or bottle.

Experiment 12 Testing surface tension

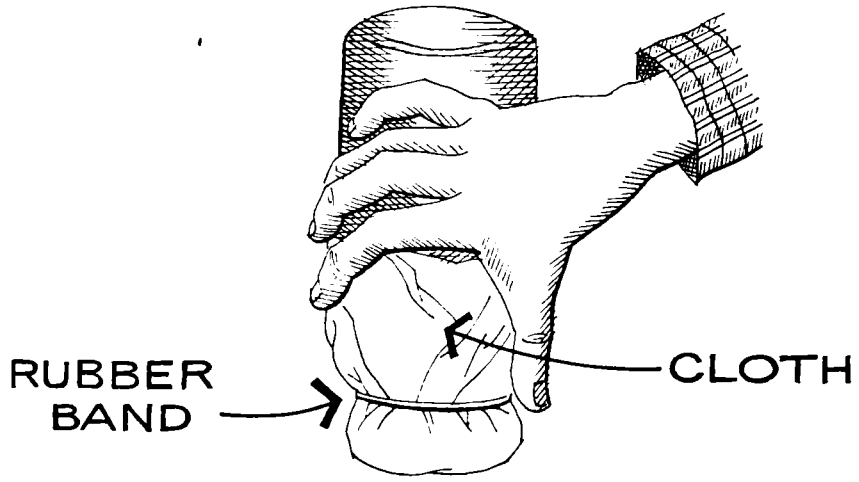
This experiment illustrates how we can use simple knowledge to understand and explain complex processes. Part A has to do with surface tension; Part B, with reduced air pressure. These experiments are apt to be a little wet even if carefully done.

Materials: A tall glass jar with a wide mouth, a handkerchief, and a heavy rubber band.

Procedures: PART A

1. Place a single thickness of the cloth over the mouth of the jar. Fasten it down with a heavy rubber band.
2. Fill the jar to the top by pouring water through the handkerchief.
3. Carefully turn the jar over. Hold the cloth toward the upper part of the jar, as shown in the diagram.
4. Observe that the water will not come out of the same openings through which it went in.

Explanation: Water goes through the cloth into the jar because the *force* of the water is great enough to break the surface tension. Water does not pour out the same way it went in because the cloth has thousands of fine capillary holes. Water captured in these holes



forms a tough "water skin" which produces surface tension. Furthermore, the outside air pressure up against the cloth is greater than the pressure inside the jar.

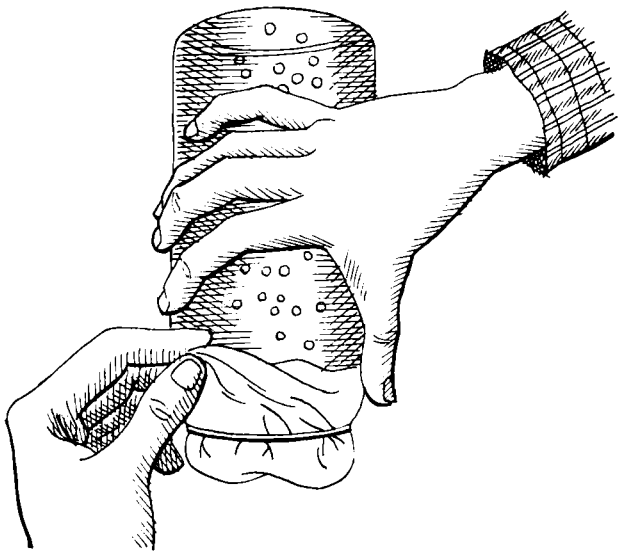
Procedures: PART B

1. Now place the jar filled with water in an upright position. Push down on the cloth to remove some of the water.
2. Tilt the jar to remove the water pushed out through the cloth. Repeat until there is a concave surface about one inch deep.
3. Carefully invert the jar as before. The water still will not pour out through the cloth because of surface tension.
4. Hold the jar firmly in one hand with the excess cloth toward the top of the jar, as indicated in the diagram. With your other hand, gradually pull up on the edges of the cloth to flatten it out at the mouth of the jar. Water will start to gurgle as you make the cloth flatter.

Explanation: You are able to cause some of the water to go out of the jar through the cloth because the force exerted by your hand is great enough to break the surface tension. When the jar is inverted, you will notice that above the water there is some space filled with air. Now the pressure above the water is equal to the air pressure under the cloth at the bottom of the jar.

When you pull up on the cloth, the part of the cloth across the mouth of the jar moves to a lower position. This increases the space above the water. Now the *same* number of air molecules have more room in which to move around. The air pressure under the jar, therefore, is greater than the pressure above the water. The air from the outside rushes into the jar through the cloth, giving the water the appearance of boiling.

This may be continued until the pressure above the water in the jar plus the pressure exerted by the water itself is equal to the air pressure under the cloth on the outside of the jar.



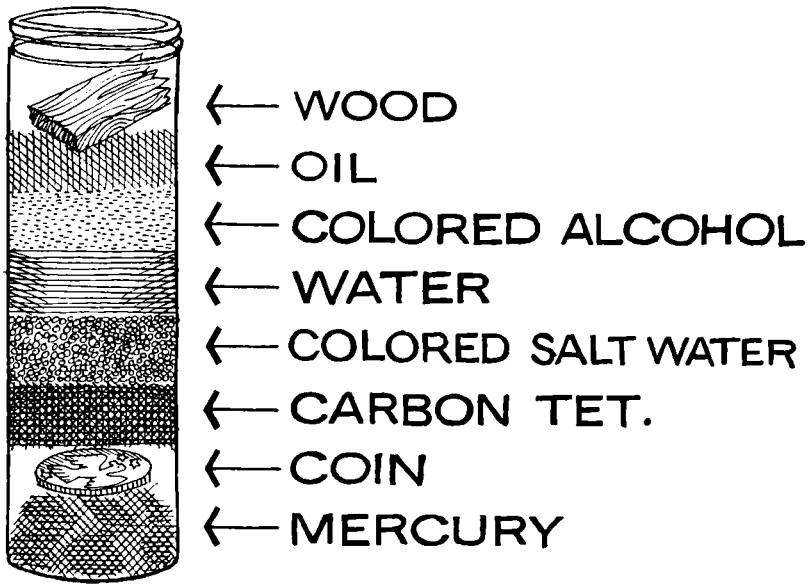
Experiment 13 Do all liquids weigh the same?

Earlier in this chapter we learned that all solids do not weigh the same per unit volume. This is also true of liquids and gases. We referred to this as the density of matter.

We can perform a simple experiment showing that some liquids are denser than others, and even denser than many solids.

Materials: A tall, narrow jar (such as olives usually come in), a penny, a small piece of wood, about three tablespoons each of mercury, colored alcohol, cooking oil, fresh water, colored salt water, and carbon tet — and air.

Procedures: Carefully put the materials in the jar in the following order. It will be necessary for you to devise a method of adding them in such a way that each addition will not disturb the material below it. Start with



the mercury, then add the coin, carbon tet concentrated colored solution of table salt and water, fresh water, alcohol, cooking oil, and wood. Of course the air will be on top. If you can't get all these ingredients, just use those that are at hand.

Explanation: The liquids and solids arrange themselves according to their densities. The heavier or more dense materials sink the farthest. Air is at the very top because it weighs the least per unit volume of the materials in the jar.

This experiment shows that liquids do, indeed, have different densities, and demonstrates why it is easier to float in salt water than in fresh water.

Experiment 14 The Bottle Imp

One of the most distinguishing properties of gases and liquids is compressibility. It is quite easy to squeeze a gas (like air) into a smaller space, but it is almost impossible to compress a liquid (like water). This difference in compressibility can be dramatically demonstrated in the following experiment.

Materials: A small bottle or medicine dropper, a tall bottle such as a quart milk bottle, and a flat pint bottle.

Procedures:

1. Invert the small, unstoppered bottle in the milk bottle almost filled with water, letting just enough water into a small bottle so that it barely floats in an upside-down position. If you can't find a small enough bottle, an ordinary straight medicine dropper will do as well.

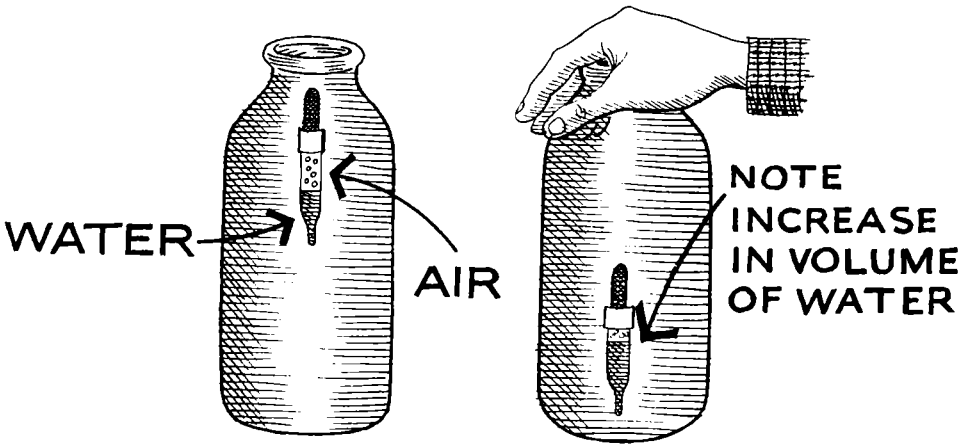
Let enough water into it so that the rubber end is just barely above the surface.

2. Now fill the milk bottle to the very brim.

3. Cover the rim of the milk bottle with the palm of your hand. Press down on the rim with your palm. The bottle inside sinks.

4. Carefully adjust the pressure applied by your palm. Observe that you can make "Bottle Imp" hesitate in any part of the milk bottle. You may want to add a little food coloring to the water in either the small or large bottle, or in both.

Explanation: Air is easily compressible. Water, on the other hand, can hardly be compressed at all. The pressure you apply on the water does not compress the water but does compress the air in the small bottle. This allows more water to enter the small bottle, and thus it loses its buoyancy and sinks. The depth to which the Imp sinks is determined by the amount of water that enters the small bottle. When the hand pressure at the top of the milk bottle is reduced, the compressed air in the small bottle forces the water out, and the Imp ascends.



Would you like to amuse your friends by using the knowledge we just learned in this experiment? Then show them that it is possible to squeeze a bottle. Take a flat-sided pint bottle and fill it to the top with water. Next, add just enough water to a medicine dropper so that the rubber tip is a little above the surface. Screw on the cap firmly. Now take the bottle in both hands and squeeze it firmly. You can make the Bottle Imp go up and down at your command. The explanation for this is the same as that given previously (along with the fact that glass will "bend" ever so slightly but enough to change the pressure).

Experiment 15 The obedient can

Among the many properties of solids, one of the most interesting is elasticity. Rubber bands have this property. A rubber band can stretch and twist because its molecules are able to change their positions with ease when force is applied to it. When the force is removed, the band returns almost to its original position and shape. We can use this special property of a rubber band in making our "obedient can."

Materials: A coffee can, a rubber band, a weight (lead sinker or washer), two matchsticks, a nail, and a hammer.

Procedures:

1. With the nail, puncture a hole in the bottom of the coffee can and another in its cover. These holes must

be in the center. Smooth the holes with a file or sandpaper.

2. Thread the rubber band through one hole. Fasten this end with a matchstick.

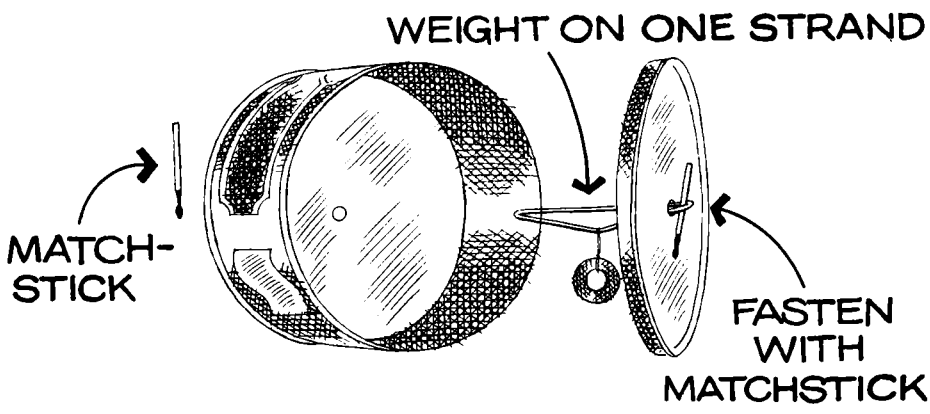
3. Attach the weight securely to the band about halfway in the can.

4. Pull the other end of the band through the opening in the cover. Fasten it with a matchstick. Close the can.

5. Roll the can on the floor. Just before it stops, speak to it. Tell it to return to you. It will.

You will want to experiment with different sizes of rubber bands and weights to obtain better results.

Explanation: The weight acts as the force that causes the band to twist. The harder the original push, the more the rubber band will twist. When the energy given the can by the push is used up, the can will stop. Now the band has stored energy by which it can return to its original position and shape. In so doing, it causes the can to roll to the sender. Needless to say, the can will return whether or not you speak to it, for it is "obeying" the laws of physics and not your voice.



3

HEAT

Introduction

Can you imagine what this world would be like without heat? It would be a solid mass of ice and stone. No life would exist upon its surface, for heat makes possible the growing of plants and animals. It also makes possible the many conveniences we enjoy every day. We know that our main source of heat and light on this planet is our sun.

Fire is another important source of heat. Probably the first fire was started by a flash of lightning. However, man found fires very useful and he was not willing to depend on lightning to start them. Somewhere in the history of civilization he learned to make his own fire by rubbing sticks together, and later by using flint. Much later the invention of the common match made fire easily available to everyone.

Heat is our great servant. It is also our great destroyer when not used wisely. Let us learn some of the important principles of heat to understand what it is and how it helps us.

What is heat?

We know that all gases and most solids and liquids are made up of small particles called molecules. We also know that molecules are always in motion in all

three forms of matter. When the hands are rubbed rapidly, a wire is bent back and forth many times, an object is hammered, or a thumb is rubbed briskly on the desk, the temperature goes up. Right now, rub your thumb rapidly on a smooth surface. How does it feel? Yes, it is possible to rub it long and fast enough to have a "toasted" thumb. This increase in temperature, in all the cases we mentioned, is produced by making molecules move at a high rate. As we increase the movement of molecules, we increase the temperature. As we decrease the movement of molecules, we lower the temperature. We can say that *heat is a form of energy produced by rapid motion of molecules.*

What effect does heat have on solids, liquids, and gases?

When objects are heated and the molecules move faster, they also move farther apart. This increase in distance between molecules causes an object to expand. All three forms of matter generally expand on heating and contract on cooling. The amount of expansion and contraction differs for different substances. Physicists, engineers, and other scientists must take this expansion into consideration in planning for materials that go into such things as bridges, tall buildings, railroads, fillings for teeth, parts for space missiles, and artificial parts for the human body.

How can we measure temperature?

Our bodies are not very accurate instruments for measuring temperature. We know that in the same

room one person may feel cold and another person warm. Scientists, of course, use an instrument called a thermometer to measure temperature. The most common accurate thermometers contain mercury, which is a silverlike metal. A mercury thermometer works on the principle that mercury expands on heating and contracts on cooling. The numerical scale on a thermometer is put on at a factory. This process is called graduating or calibrating a thermometer. After you read this chapter you will be able to make a thermometer of your own, though it may not be as accurate as a thermometer you buy.

There are two kinds of thermometers. The kind that is used in most homes gives the temperature reading according to the Fahrenheit scale. This is the scale we normally use when discussing the weather outside, the temperature of an oven, and the temperature of our bodies. The freezing point of water on this thermometer is 32°F, and the boiling point of water on it is 212°F. Scientists use the Centigrade thermometer in all their experiments. The freezing point of water on the Centigrade scale is 0°C, and the boiling point of water is 100°C. A reading of 32°F is the same as 0°C; a reading of 212°F is the same as 100°C.

Where do we use principles of heat?

In addition to the use of heat for cooking our food, we also use principles of heat to cool our foods. Gas or electric refrigerators make our foods cold by taking heat away.

Most of our houses are heated either by forcing warm air through them or by having hot water circulate through radiators.

Industries use heat to melt ores, to vulcanize rubber, to sterilize containers, to weld parts together, to dehydrate foods, and to perform many other tasks. Scientists are experimenting to find out how to heat highways inexpensively to keep snow and ice from forming on them during winter months.

Our weather changes as a result of changes in temperature. Warm air can hold more moisture than cold air. When the temperature of warm air falls, dew, frost, or fog may form because the cooler air cannot hold as much moisture. Likewise, winds are affected by changes in temperature. Winds are caused by denser, cooler air rushing to fill the space occupied by the more expanded and lighter warm air. We have used some of these principles in the previous chapter.

Experiment 16 Do solids expand on heating and contract on cooling?

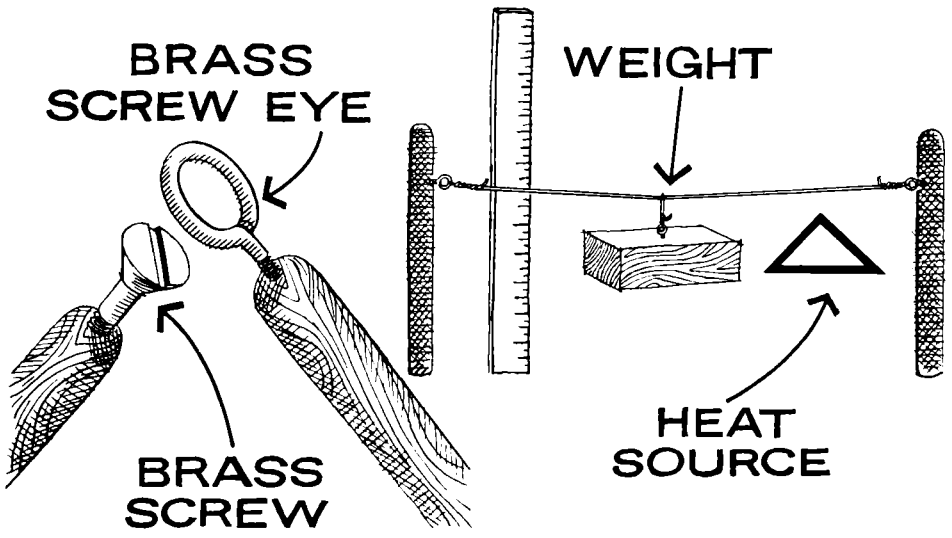
Materials: For this experiment you will need a heat source, a screw eye of the size used to fasten screens, a brass wood screw, the head of which will *just* fit through the screw eye, 2 one-foot pieces of wooden broomstick, about 3 feet of thin copper wire, about a ½-pound weight (you may use washers or a small can filled with sand), a ruler, and a couple of supports.

Procedures: PART A

1. Screw the brass screw into one of the pieces of broom handle and the screw eye into the other one. It may be necessary to file the head on the brass screw to make it just fit through the screw eye.
2. Hold the rod with the brass screw in a flame for several minutes. Try to run it through the screw eye.
3. Pour cold water over the screw and again try to run it through the screw eye.
4. Heat the screw and the screw eye simultaneously. Try to run the screw through the screw eye. Will it go through now?
5. Be sure to record your observations.

PART B

1. Stretch the copper wire between two supports on your lab bench.
2. Fasten the weight in the middle of this wire as shown in the diagram.
3. Heat the long piece of wire with a candle or alcohol lamp.



4. Observe what happens to the weight. Measure the distance of the bottom part of the weight from the table top before and after heating.
5. Let the wire cool off and measure the height of the weight.
6. Instead of copper wire, you may want to try some other type of wire, such as fence wire or a coat hanger.
Explanation: When the brass screw was heated, the molecules within it moved faster and therefore farther apart, and this caused the screw to expand. Consequently, the head on the screw did not fit through the screw eye. Upon cooling, the screw contracted because the molecules moved more slowly and again came closer together, allowing the screw to fit through the eye. When they were heated simultaneously, they both expanded, and for this reason it was possible to run the screw through the screw eye. This experiment works best when both parts are made of the same metal.

When wire is heated, it also expands. The weight makes this expansion easier to observe. Upon cooling, the wire contracts and the weight returns to its original position — or almost to its exact original position.

Experiment 17 Do all materials start to burn at the same temperature?

At some time you have probably started a fire indoors in a fireplace or outdoors while camping. In starting the fire the materials were organized in somewhat this or-

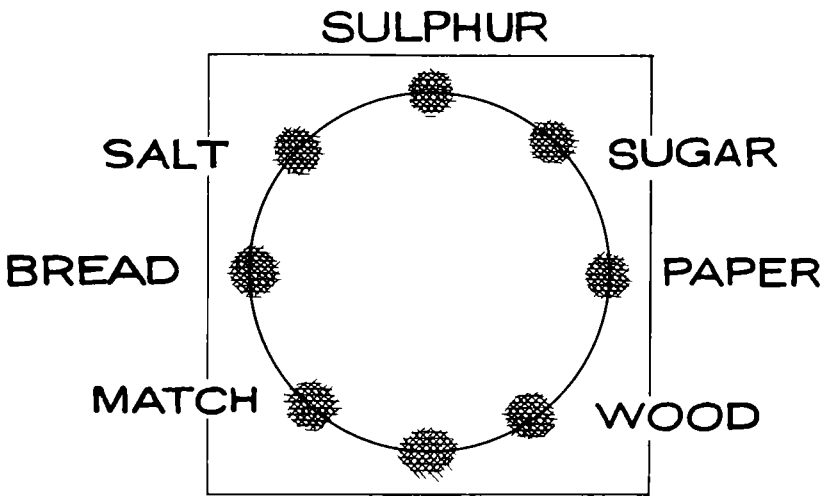
der: paper at the bottom, then small sticks, larger sticks, and finally coal or coke. Why was this order necessary? Let's find out by doing this experiment.

Materials: Metal pie plate, a match head, salt, pieces of sulfur, bread, paper, sugar and wood.

Procedures:

1. Take the metal pie plate and find its center. Mark it with a pencil on both sides.
2. Place some of the following materials at equal distances from the center: sulfur, match head, bread, coal, paper, wood, stone, and salt. Be sure they are all about the same size and a safe distance from each other.
3. Place a lighted candle or alcohol lamp underneath so that the flame strikes the center mark.
4. Observe which materials char first, which burn first, and which are not affected at all.

Explanation: The materials will start burning in this order: sulfur, match head, sugar, bread, paper and wood. The salt is unaffected by the heat. The order may



vary slightly depending on the distance the materials are from the center. They char and burn at different temperatures because of the type of molecules that make them up. Some molecules combine with oxygen more easily than others. The temperature at which anything starts to burn is called the kindling temperature. Of the common materials used in making fires, paper has the lowest and coal the highest kindling temperature.

Experiment 18 Do gases and liquids expand on heating?

Materials: A source of heat, a flask, a one-hole stopper, a 12-inch piece of glass tubing or a clear plastic straw (either of which will fit firmly in the stopper), a balloon, a thermometer, and some Scotch tape.

Procedures: PART A

1. Fill the flask about three fourths full of cold water. You may add a little food coloring to the water to make it easier to observe and take readings.
2. Take the temperature of the water. Be sure to record this.
3. Moisten the glass tube (or straw) and push it through the stopper. Put the stopper tightly into the flask, and adjust the tube so that the level of the water in the tube is just above the top of the stopper. Wrap a narrow strip of Scotch tape or string at the water level.
4. Place your hands around the flask to warm the wa-

ter. Of course, your hands must be warmer than the water. Observe that the water in the tube will rise a little after a few moments. (The water may sink a little at first because the flask itself expands.)

5. Now place the flask over a flame. Notice that the water rises up the tube very swiftly.

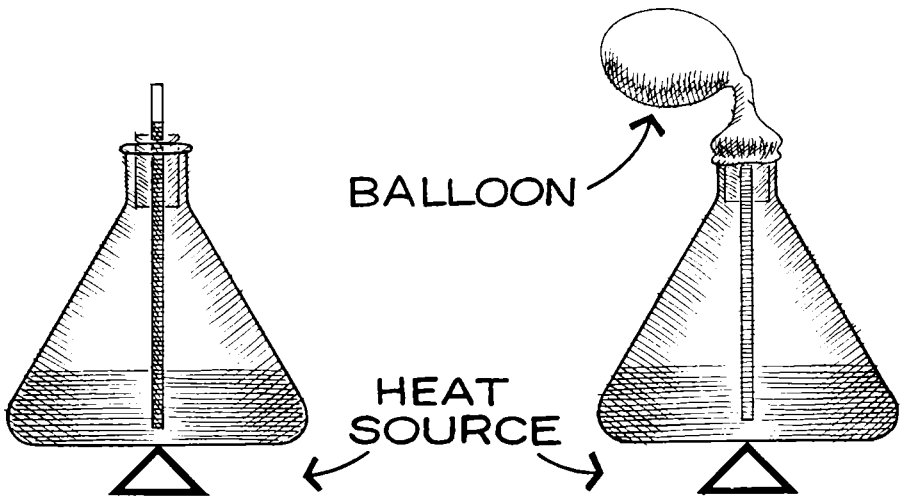
6. Remove the stopper with the tube and take the temperature of the water. Compare this reading with the one in step 2.

PART B

1. Pour the water out of the flask and attach a balloon to either the tube or the mouth of the flask.

2. Heat the flask, first with your hands and then with a flame. You will see that the balloon inflates as the temperature of the air in the flask increases.

By doing this experiment several times, always beginning with water or air at the same temperatures, you can show that the higher the water is in the tube, or the more inflated the balloon is, the higher is the temperature of the water or the air.



Explanation: Most liquids expand on heating. During the heating, the water molecules move faster and therefore farther apart, and thus occupy more space. In this experiment, the only place these molecules can go is up the tube. On cooling, the opposite change takes place. This apparatus may be used as a rough "thermometer."

In Part B of the experiment, the air in the flask expands. This causes the balloon to become inflated. On cooling, the air contracts and the balloon becomes smaller.

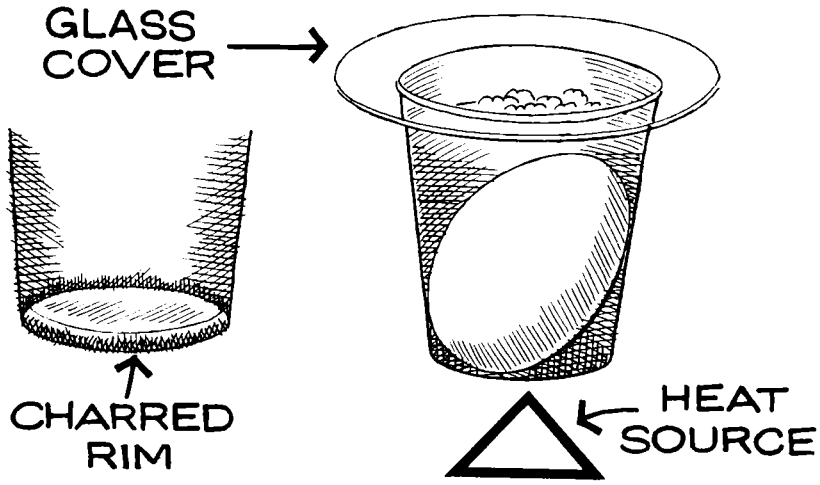
Experiment 19 Can we boil water in a paper cup?

Many of us have seen and marveled at magic performed by so-called magicians. The stunts they do are simple once the secret is known. Take, for example, the boiling of water in an ordinary paper cup. Yes, you can do this by following several simple directions. You can not only do this "magic," but you will also know how the experiment works.

Materials: A paper cup *without a false bottom,* a hot plate, and an egg.

Procedures:

1. Fill the paper cup about half full of water from the faucet.
2. Place the cup with the water on the hot plate. You may use an alcohol lamp instead of the hot plate. When using the alcohol lamp, a piece of wire screening



should be used between the flame and the cup. This helps to distribute the heat.

3. To hasten the boiling, place a piece of cardboard or a small glass plate over the top of the cup.

4. Take the temperature of the water at several different times.

Explanation: The paper cup will not burn because water is an excellent absorber of heat. The water absorbs the heat so fast that the bottom of the cup never gets much hotter than the water in the cup, and, of course, paper will not catch on fire at 212°F, which is the boiling point of water. A cover will hasten the boiling of the water, for it helps to decrease the rate at which heat is lost.

You can even boil an egg in the cup if you wish. Let it boil for about five minutes — longer if you want it hard-boiled.

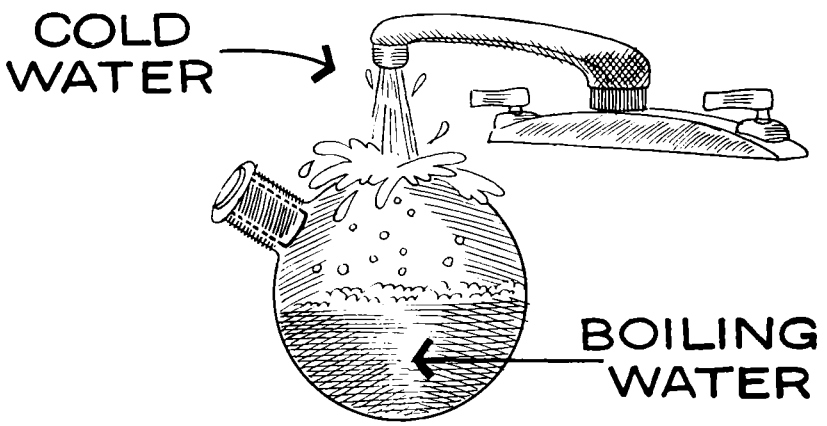
The cup may char along the lower rim if it has a false bottom, for there is no water to take away the heat from the false-bottom part of the cup.

Experiment 20 Can ice cubes make water boil faster?

Materials: Round-bottom Pyrex flask, a stopper, a heat source, cold water or ice cubes, a dishpan, and a couple of hot pads. Note: A flat-bottomed flask *must not* be used. The flask *must* be rounded on the bottom, and resemble a sphere with a neck.

Procedures:

1. Fill the flask about half full of water, and boil it until all the air above the water is driven out by the water vapor. This will take about 20 seconds of constant boiling.
2. Remove the flask from the flame and immediately insert the stopper firmly. Observe whether or not the water is still boiling.
3. Carefully pour cold water from the faucet over the flask. To hasten the rate of boiling, place crushed ice over the top of the flask. Observe the rate at which the water boils as colder materials are placed over the top of the flask.



4. Feel the flask while the water is boiling under these conditions.

Explanation: The water continues to boil even though the heat is removed and the temperature drops below the boiling point of water at room pressure. When cold water or ice is placed on the outside of the stoppered flask, the water vapor above the water condenses. Condensing the water vapor reduces the pressure above the water slightly. The vapor pressure exerted by the water is then enough to cause the water to continue to boil. Water can be made to boil at very low temperature by reducing the pressure above the water. For this reason it takes longer to cook an egg at high altitudes where the pressure of the atmosphere is less than at sea level.

It is not the boiling that cooks food; it is heat which does the cooking. In a pressure cooker, the water may not boil but the temperature is usually over 212°F, which is the boiling point of water at ordinary pressure.

Experiment 21 Putting out a fire chemically

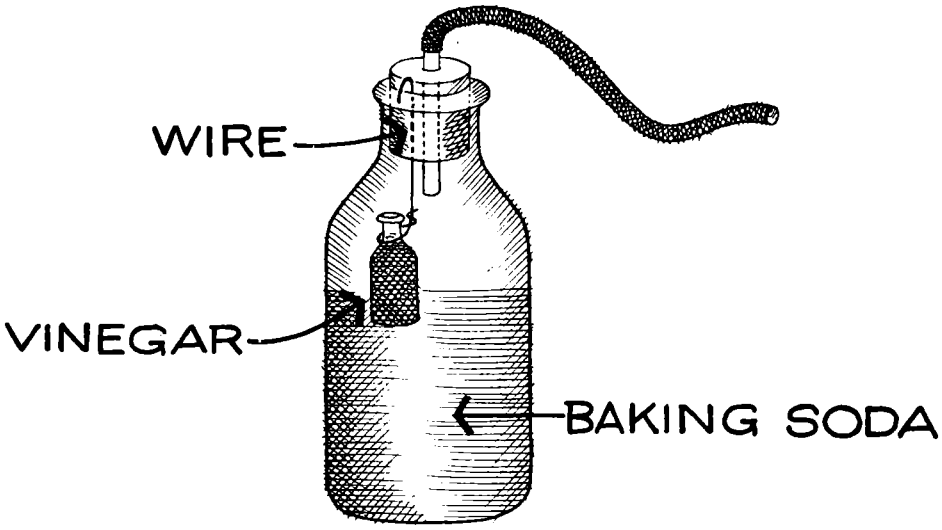
All of us have heard a great deal about fire extinguishers. Most of us, however, know no more about them than that they are used to put out fires. There are at least four different types of extinguishers, namely: carbon tetrachloride, solid carbon dioxide, powder, and soda-acid extinguishers. In this experiment we shall learn about the operation of the soda-acid extinguisher.

Materials: A pint bottle, one-hole stopper to fit this bot-

tle, a small bottle that will fit into the pint bottle (a litmus-paper bottle will do), baking soda, vinegar, a 2-inch piece of glass tubing, and about 6 inches of rubber tubing.

Procedures:

1. Fill the large bottle half full of water, and add to it two tablespoons of baking soda. Shake the contents well.
2. Fill the small bottle with vinegar. Suspend it in the large bottle by means of wire or string. See the diagram. The baking soda solution must not mix with the vinegar at this time.
3. Place the short piece of glass tubing through the hole in the stopper, and attach the rubber tubing to it.
4. Insert the stopper into the bottle firmly. You now have a working model of a regular soda-acid fire extinguisher of the kind you often see in public buildings.
5. The next thing you need is a fire to put out (and your parents should be around for this). Crumple up a sheet of paper and place it in an old pan or soup dish. Light it. After the fire gets a good start, turn the large bottle over and direct the rubber tubing toward the fire. Hold the bottle so that your fingers are over the stopper. This will prevent the stopper from being pushed out, should the pressure become too great.
6. Another way you can do this same experiment is to take a rectangular cake pan and at one end place a *short* burning candle, and at the other end a drinking glass with a baking-soda solution. Now add a few drops of



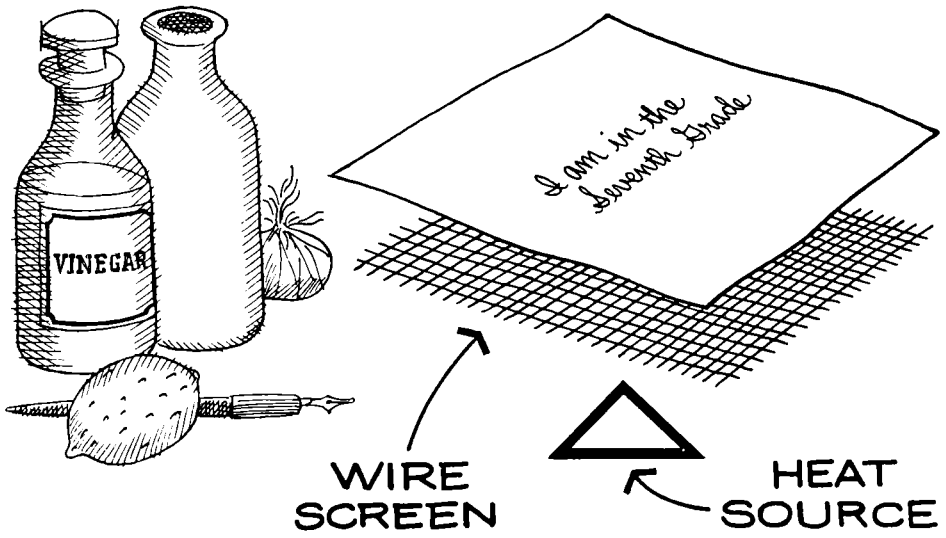
vinegar to the solution. It may be necessary to bring the glass toward the burning candle.

Explanation: When the bottle is turned over, the vinegar mixes with the baking-soda solution. Carbon dioxide gas is formed. The strong pressure in the bottle pushes the water along with the carbon dioxide out of the tube. The carbon dioxide (CO_2) gas forms an envelope over the fire. This prevents oxygen gas from entering and supporting the fire.

The large soda-acid extinguishers in schools work on this same principle. They contain a saturated baking-soda solution and sulfuric acid. Never aim the hose of this, or any other extinguisher, toward a person's face.

Experiment 22 Invisible writing

Materials: An alcohol lamp or a match, a small piece of wire screening, and any one of the following: vinegar, milk, lemon juice, grapefruit juice, or onion juice.



Procedures:

1. Take one of the fluids and use it in place of ink. With a clean pen, write a message on semiporous paper. The writing should be heavy.
2. Allow the "ink" to dry at room temperature. The message should disappear.
3. Place the wire screen in back of the paper and bring the paper over a flame. Gently move the paper back and forth high above the flame to prevent the paper from catching on fire.
4. Make your observations for the different inks you used.

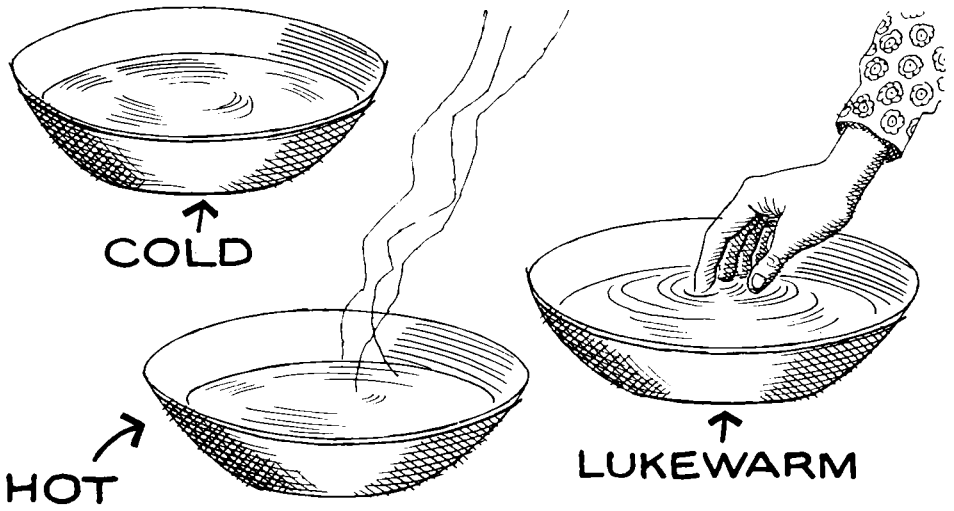
Explanation: The above fluids, after the water has evaporated from them, leave residues that have lower kindling temperatures than the paper on which they were used. The area where the writing was made will char when exposed to gentle heat. The color of the writing is determined by the nature of the juice that is used. You may want to experiment with additional juices.

Experiment 23 How accurate are our hands for recording temperature?

Materials: Three 2-quart containers.

Procedures:

1. Fill one pan with hot water, the second with lukewarm water, and the third with very cold water.
2. Place your right hand in the hot water and at the same time your left hand in the cold water. Hold your hands in the water for a few seconds.
3. Remove your right hand from the hot water and place it immediately in the lukewarm water. How does the water feel?
4. Now remove the right hand from the lukewarm water. Place your left hand in the lukewarm water. How does it feel?
5. Again, place your right hand in hot water and your left hand in cold water. Leave each hand in the water for several seconds.



6. Quickly place the hand from the hot water into the cold water, and the hand from the cold water into the hot water. Record your feelings.

Explanation: The experiment shows that our hands or other parts of our bodies are not reliable for measuring temperature.

The hand that was placed first in the hot water and then in the lukewarm water felt much cooler than the actual temperature of the lukewarm water. This was caused by the sudden slowing down of the molecules that bombarded the hand. The hand that was in the cold water felt very warm when it was placed in the lukewarm water. This was caused by the immediate increase in the speed of the molecules that were hitting the hand.

In all cases, the sensation we have when our hands are placed in water of different temperatures is much greater than the actual difference in temperature between the water in the two containers.

Experiment 24 Do all materials conduct heat at the same rate?

Materials: Test tube, match, a half dollar, a piece of cloth, paper, stick of wood, metal rod, and a heat source.

Procedures:

1. Fill the test tube with water and hold the top of the tube in the flame. Observe what happens to the water

in the top of the tube while you are holding the bottom of the tube in your hand.

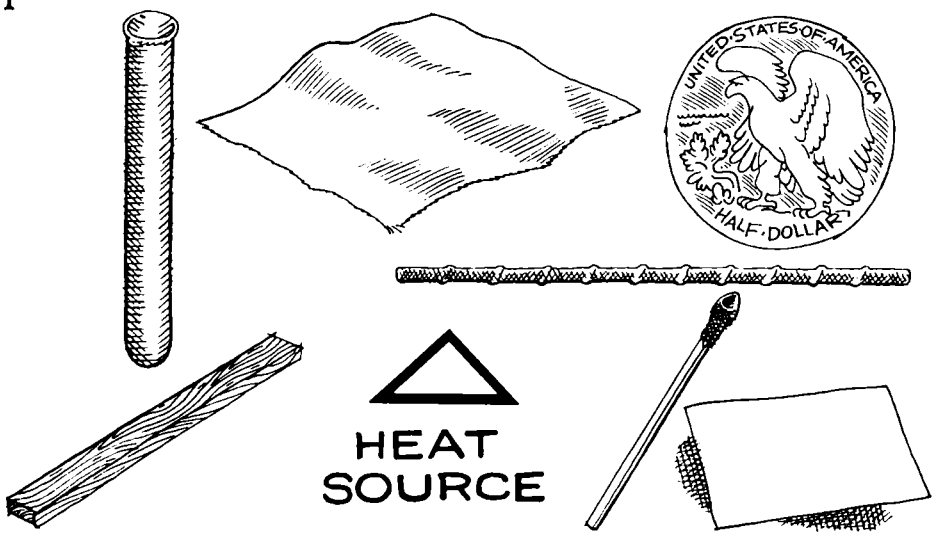
2. Light a large match. Is the matchstick warm?

3. Place a stick of wood in the flame. When will you start feeling the warmth?

4. Place a piece of paper around a copper or brass rod. Using the paper for insulation, hold the rod in the flame. Examine the paper and feel the rod.

5. Take the coin and place a single thickness of cloth over it. Be sure the cloth is *tight* over the coin. Bring a candle or alcohol flame under the cloth. Examine the cloth and feel the coin.

Explanation: Not all substances conduct heat at the same rate. Water will boil in the upper part of the tube without your feeling the heat in the bottom part because water is a poor conductor of heat. Wood, as in the case of the match and the stick, is also a poor conductor of heat. Copper, brass, and silver are good conductors of heat. The cloth did not burn even though the flame came in contact with it because the metal conducted the heat from the cloth before its kindling temperature was reached.

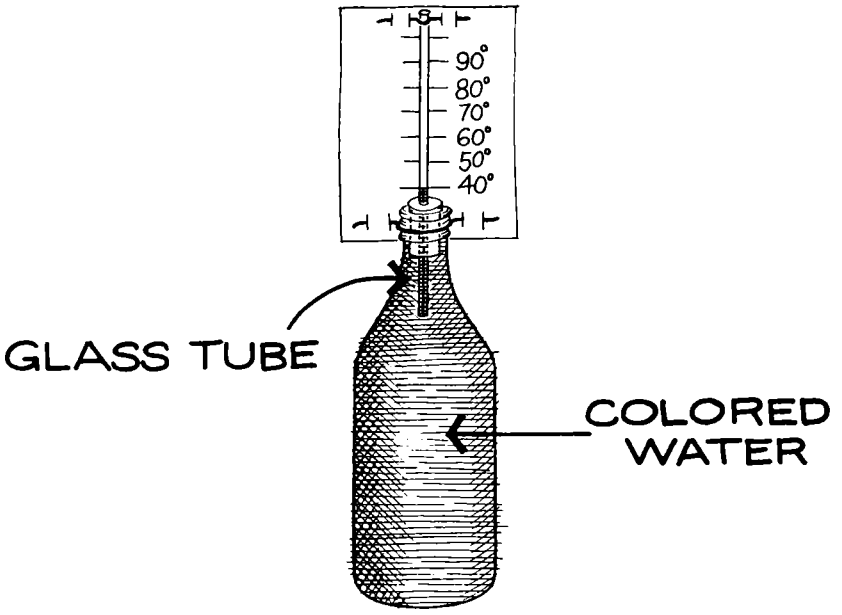


Experiment 25 How can we make a simple thermometer?

We use a ruler to measure short distances, and balances to measure weights. In a similar fashion, we use a thermometer to measure how hot or cold a substance is. Distance is expressed in inches or feet; weight, in ounces or pounds; and the temperature of materials, in degrees.

A thermometer can be used to measure the degree of temperature because substances expand on heating and contract on cooling. This we showed in previous experiments. In this experiment we shall use the oldest of temperature-measuring instruments — a water thermometer.

Materials: A pint or quart bottle (the thinner the glass, the more sensitive the instrument), a one-hole stopper to fit the bottle, a plastic drinking straw or six-inch glass tube, food coloring, a candle, and a 3″ x 5″ card.



Procedures:

1. Fill the bottle with water and add a few drops of food coloring to it.
2. Push the tube through the stopper, and insert this in the neck of the bottle. It may be necessary to add more colored water through the open end of the tube. The height of water in the tube at the beginning should be about one fourth of the way up the tube. Use a medicine dropper to add the water.
3. Seal the tube to the stopper with candle wax. You may want to add a few drops of oil on top of the colored water to prevent evaporation. For measuring low temperatures, it will be necessary to use half water and half rubbing alcohol in the bottle to prevent freezing.
4. Fasten the white card behind the tube as shown in the diagram.
5. Place the thermometer on the window sill. Make a mark on the card behind the level of the liquid. Obtain a reading from a purchased thermometer, and place this value beside the line on the card. (Of course the purchased thermometer must be in the same place as the water thermometer!) Obtain other readings and mark them on the card. You are calibrating the thermometer. When you have obtained enough readings, you no longer need the purchased thermometer and can rely on your own.

Explanation: Your thermometer works because most liquids expand on heating and contract on cooling.

4

SOUND

The meaning of sound

Sound is caused by objects moving back and forth at a very rapid rate. Vibration, as this motion is called, may be set up in solids, liquids, or gases. A vibrating object like a tuning fork or a stretched rubber band will cause the surrounding air particles to vibrate also. On reaching our ears, these air particles cause the eardrums to vibrate. The sensations caused by such vibrations are sent by means of nerves to the brain. It is the brain that interprets the various sounds for us. Thus, to experience sound, we need a vibrating object, a medium (or material) to carry the vibrations, and a brain to interpret them.

Properties of sound

A knowledge of the properties of sound will make it possible for us to understand better the experiments that follow, as well as many other aspects of sound.

Sound does not travel at the same speed through the three forms of matter. It travels slowest through gases (air), faster through liquids (water), and fastest through solids (steel).

Sound travels at 1100 feet per second through air

when the temperature is 20°C, or 68°F. For every increase of 1°C, the velocity of sound increases nearly two feet per second.

Sound travels in circles or in a spherical wave front. The circles or waves in which sound travels are very similar to those formed when you throw a stone into still water. The waves spread out equally in all directions from the point where the stone strikes the water.

Sound waves can be bounced back and forth from certain surfaces. When this happens we have an echo. We have learned how to decrease the reflection of sound waves in our homes and in large buildings. This is done by using heavy draperies or various acoustic (a-koos'tik) materials. You have, no doubt, seen acoustic tiles on ceilings in homes, schools, and other buildings. Most acoustic tiles have little holes. Sound waves are captured in these holes. The energy is used up as the waves bounce back and forth within the holes.

Uses of sound

Ancient man knew about sound. He tracked down wild animals for food and avoided dangerous animals partly by using principles of sound. Indians, likewise, made use of sound waves. In dangerous territories they placed their ears to the ground to learn about the possible approach of enemies, for the ground conducts sound waves better than the air does. People in all civilizations have used principles of sound to make a variety of musical instruments. They have done this by beating on hollow drums, by striking certain metals, by blowing

into horns, and by plucking strings stretched across wooden frames.

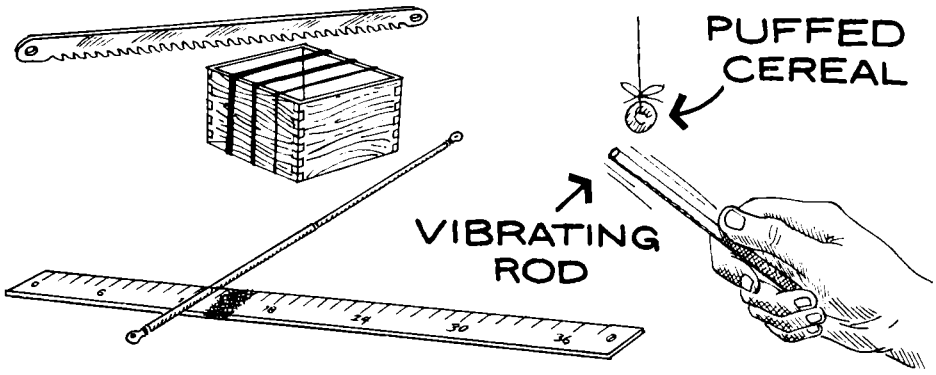
Modern man uses sound in one form or another in thousands of ways, not only to communicate by voice but also to delight his ear with the rich and varied sounds of music. He uses it in unexpected ways as well; for example:

1. To measure the depth of ocean bottoms or to locate objects under water. We refer to this as the sonar method.
2. To locate minerals and fuels under the ground.
3. To clean cavities of loose particles prior to repair.

Experiment 26 What is sound?

Materials: A hack-saw blade, a small wooden box, a solid curtain rod or other metal bar, rubber bands of different widths, a shallow dish, and a few grains of puffed cereal.
Procedures:

1. Hold the hack-saw blade firmly against the desk so that about one inch of the blade extends beyond the desk. Strum it. Repeat this several times, each time allowing more of the blade to extend beyond the desk.
2. Take a yardstick and put it on the desk with about three inches extending beyond the desk top. Strum it. Repeat several times, each time allowing more of the stick to extend beyond the desk. Compare the results with those obtained with the saw blade.
3. Place different-sized rubber bands over a small



wooden box or a deep cake pan. Strum each one separately. Stretch some bands more tightly than others. Strum again. Record your observations.

4. Take the metal rod and strike it against your heel. Place the vibrating end in a dish of water. Hit the rod again, but this time bring the vibrating end near a suspended grain of puffed cereal. Strike the rod again and put the nonvibrating end back of your ear, then on your teeth. What do you feel in each case?

Explanation: In each case, sound was produced because the materials were set in vibration by applying force to them. By using different lengths, thicknesses, and materials, the pitch was changed. The longer and thicker the material, the lower the pitch.

In step 4, you could actually see the vibrations in the water, or their reaction on the grain of cereal, and you could feel them as well as hear them.

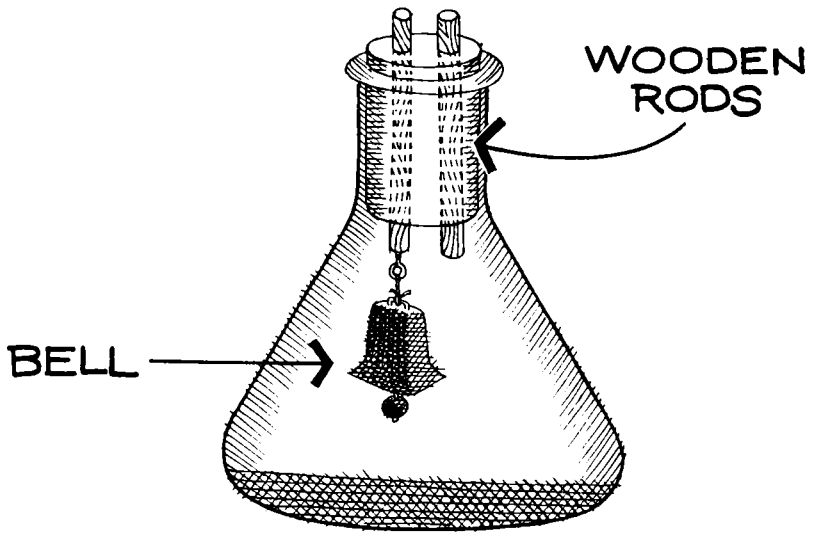
Experiment 27 Does sound travel in a vacuum?

Materials: Pyrex flask, a two-hole stopper to fit the flask, a wooden or glass plug for one hole in the stopper, a

small bell, a wooden rod, heat source, stand and iron ring.

Procedures:

1. Fasten the bell (you may use a miniature sleighbell) to one end of a wooden rod and pass this rod through one of the holes in the stopper. It must fit *very* tightly.
2. Place about one-fourth cup of water in the flask and insert the stopper with the bell. Shake the flask and listen.
3. Boil the water until the water vapor has driven out all of the air. Most of the air will be driven out when most of the water has evaporated.
4. Remove the flask from the burner and immediately insert the plug in the other hole in the stopper.
5. After the flask cools, shake it. Compare the loudness of the bell with its loudness in step 2 above.
6. Remove the plug slowly, at the same time shaking the flask. What do you notice about the intensity of the sound?



Explanation: Sound will be heard when there is air in the flask. Sound is not heard — or is only faintly heard — when the flask contains a partial vacuum. The water vapor drove out the air particles. As the water vapor condensed, the pressure in the flask decreased. This caused a partial vacuum. The better the vacuum, the less sound can be heard. Sound must have one of the three forms of matter by which to travel. Some of the sound waves from the bell will leave the flask by means of the rod, but the lack of air prevents the sound waves from traveling easily.

Experiment 28 Changing the pitch of sound with water in glasses

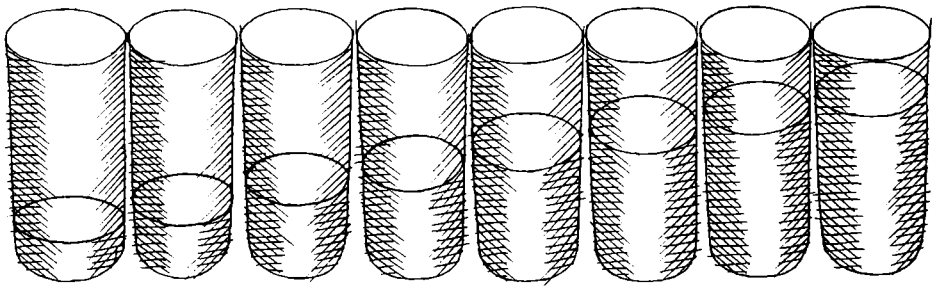
Before producing this "pop concert," rub your fingernail slowly across the rough cover of a book. If you have the nerve, you may try rubbing it also over a chalkboard, should you have one at home! As the fingernail vibrates, a low sound is produced. Next, pass your fingernail across this book, but this time move it a little more quickly each time. As you increase the movement, you also increase the number of vibrations per second. In everyday language, we say that the pitch was increased; that is, the sound tone became higher and higher. The more times per second a material vibrates, the higher the musical tone; the fewer the vibrations per second, the lower the musical sound. Now, just for the fun of it, pass your index finger over the teeth of a

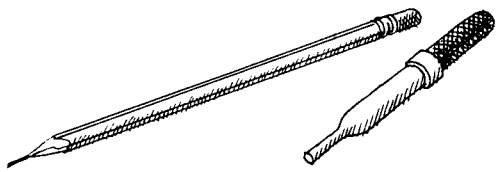
comb. If you're skillful enough, you can hear a cat *mee-ow*.

Materials: Eight tall water glasses of the same size and shape or eight pop bottles, a pencil, and a medicine dropper.

Procedures:

1. Fill one glass to the top with water. Strike the glass with a pencil, a knife handle, or some other hard object, and listen for the sound produced.
2. Put less water in the second glass, enough to produce the next lower note of the scale when you strike the glass with your pencil or knife handle. A medicine dropper will help you to make fine adjustments of the water level.
3. Put successively smaller amounts of water in each of the other six glasses. Test for the proper note and add or subtract water from the glasses until each one has the correct pitch. The first glass should be one octave higher in pitch than the last.





4. If you have tuned the glasses properly, you can actually play a tune on them by tapping them with the pencil.

5. A similar experiment may be done with eight pop bottles. First you have to be able to play a note on the bottle by blowing across its top. Once you have acquired this skill, you can make a set of pop bottles by filling them with different amounts of water as you did with the water glasses. The result is a crude sort of pipe organ.

Explanation: In the case of the tumblers, it is the glass itself that vibrates. The water dampens the vibrations so that the more water there is in the glass, the smaller the area of the tumbler to vibrate, and the higher the pitch.

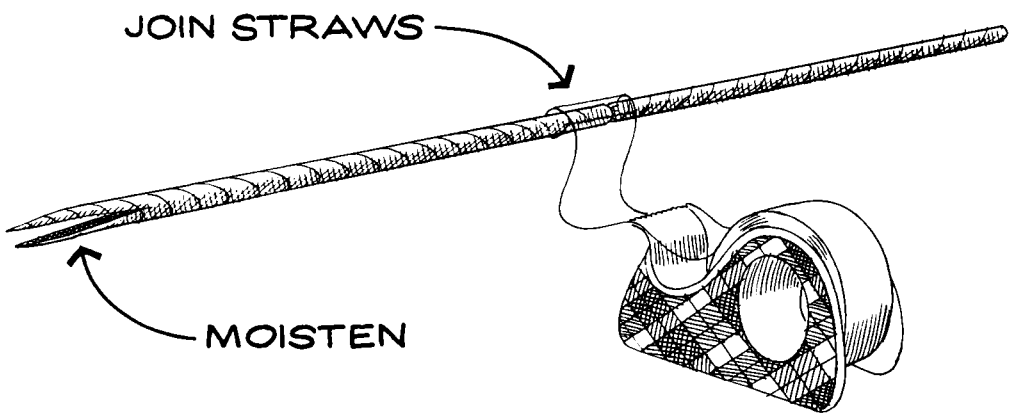
With the bottles, it is the air inside that vibrates when you blow across the top so that the more water, the shorter the column of air, and the higher the pitch of the musical note.

Experiment 29 Changing pitch with paper drinking straws

Materials: Several paper drinking straws, Scotch tape, and scissors.

Procedures:

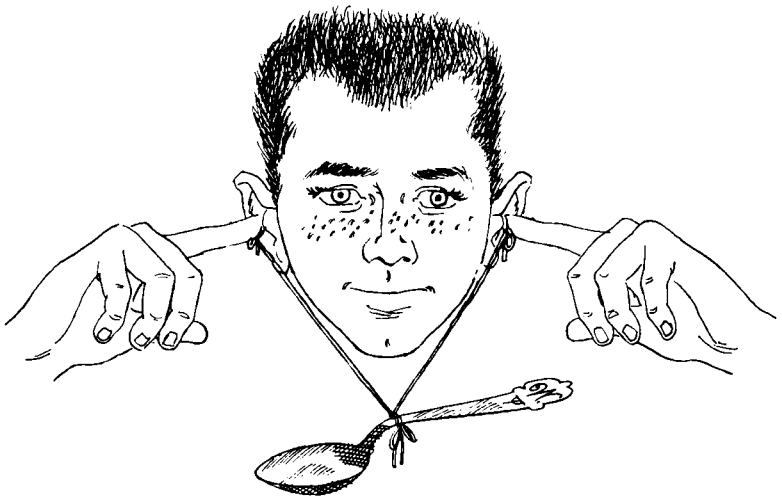
1. Blow through a straw. All you hear is the hiss of escaping air.
2. Place the straw upright and, leaving the bottom end open, blow over the top. Now blow over the top with the bottom closed.
3. Flatten one end of the straw for about one inch. Cut this portion with sharp scissors to form a point. Moisten the point slightly with your lips. Place this point in your mouth so that your lips touch the beginning of the round part of the straw. Blow into the straw.
4. While you are blowing into the straw and getting a musical note, cut off about one inch from the other end of the straw; then two inches; three inches; and so forth. Observe what happens to the pitch as you decrease the length of the tube — the vibrating air column.



5. Take another straw and make a point on one end, as above. Moisten this end and blow into it. With the use of Scotch tape, add another straw. Blow again. Add a third straw. Blow again. What happens to the pitch as you increase the length of the vibrating air column?
Explanation: The pitch of any note depends on the number of vibrations per second. The shorter the tube of air that vibrates, the greater is the number of vibrations per second, and consequently the higher the pitch.

Experiment 30 How can we get chime sounds from a spoon?

Materials: Spoons, forks, and about three feet of string.
Procedures:
1. Tie a teaspoon to the middle of the string. Make loops at each end of the string.
2. Put your index fingers through the loops and into your ears.
3. Lean over and strike the spoon against some solid wooden object, such as a chair. Describe what you hear.
4. Repeat the above experiment using a tablespoon.
5. Repeat the above experiment using a fork.
6. Repeat the above experiment using a very large spoon.
Explanation: Vibrations travel from the spoons or fork by means of the string to your eardrums. From there the nerves carry the sound waves to your brain, which interprets the vibrations as sound. Because the spoons



are curved and vary in thickness, complex sounds are produced that are rich in overtones. This causes the chime effects.

If you were to remove the string from your ears and then strike the spoon against the chair, you would notice that the sound was neither as loud nor as pleasant. This is one way to show that sound travels better through solids than through gases.

What would happen if flexible copper wire were used instead of string? Try it and see!

Experiment 31 Why we hear unusual sounds in sea shells and in milk bottles

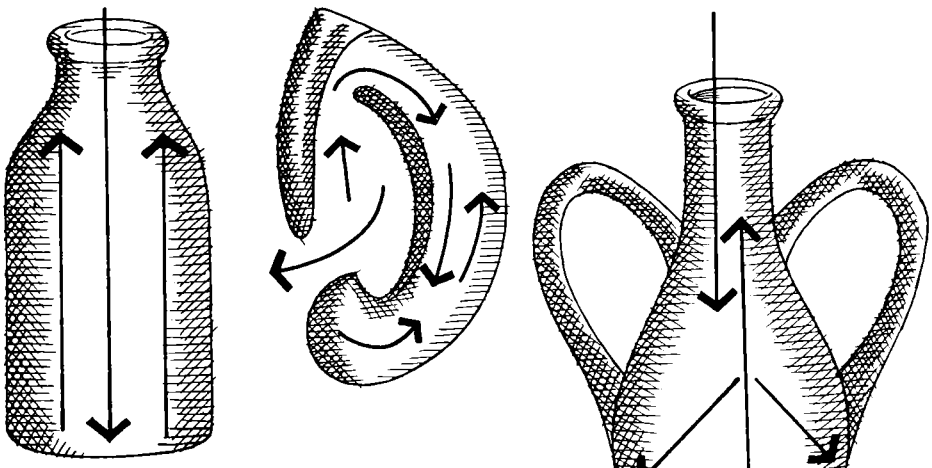
Materials: Sea shells, milk bottle, vases, etc.

Procedures:

1. Put the different containers close to your ear and listen to the various sounds produced.

2. Hold them firmly against your ear and then hold them lightly against the ear. Is there a difference?
Explanation: Sound is produced when a solid, liquid, or gas vibrates. The type of vibration is determined by the shape and size of the container, and also by the materials from which the container is made.

The wall of a container, such as that of a sea shell, is caused to vibrate by air molecules that bombard it from the outside. The vibrating wall then sets into vibration the air within the shell. The sound vibrations that exist only faintly in the air on the outside are amplified within the shell. The irregular surfaces in the shell reflect the vibrations from one surface to the other. The amplification of the vibrations and the reflection of waves from uneven surfaces help to produce the "ocean"-like sounds heard when the shell is held close to the ear.



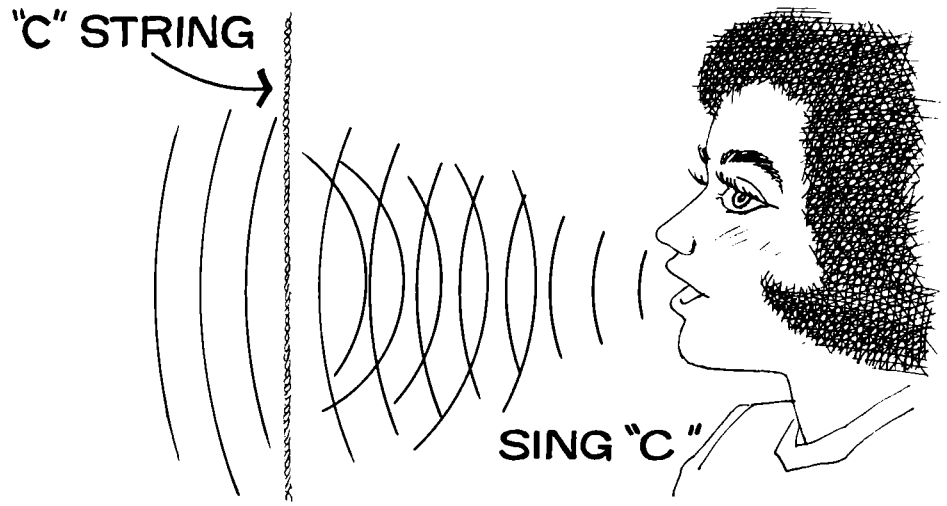
DIFFERENT SHAPED CONTAINERS SHOWING AIR MOVING INSIDE IN VARIOUS DIRECTIONS.

Experiment 32 Resonance

Materials: Piano or other stringed instrument.
Procedures:

Go to a piano, violin, or other stringed instrument. Sound any one note in order that you may hear the pitch of this note. When the sound stops coming from the instrument, sing the same note that you heard rather loudly back toward the instrument and stop suddenly. The instrument then continues to produce, although faintly, the note sung to it. When using the piano for this experiment, hold the key down while you sing and after you stop. This lifts the dampers from the piano strings so that they can vibrate.

Explanation: This experiment shows resonance. The string vibrates at a certain pitch, or number of vibrations, per second. The vibration can be started by plucking or striking the string. The vibration can also be started by sound waves of the same pitch. As each sound wave from your voice passes by the vibrating string, a little bit of energy starts the string vibrating.



The next wave strengthens this vibration, and so on until the string vibrates with enough energy to produce sound that can be heard. The two sounds are resonant with each other.

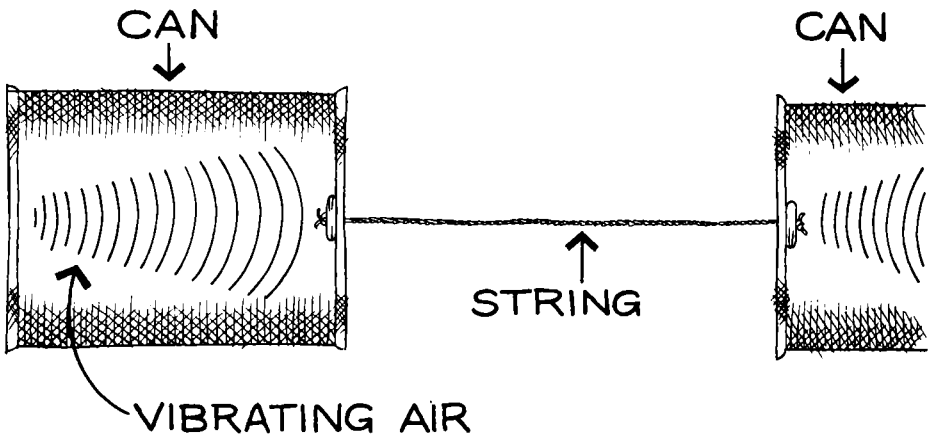
A sea shell is a similar resonator, but unlike a single string, the shell resonates or responds to sound vibrations of many different tones. Sound vibrations that exist only faintly in the air set the air within the shell into vibration. When your ear is close to the shell you can hear some of the sound vibrations of the air that are picked up by the shell in the same manner that the piano or violin string picked up and resonated with the note that you sang.

Experiment 33 How can we make a telephone using cans or paper boxes?

Materials: Two cans of the same size (or two cylindrical cereal boxes such as oatmeal comes in), two buttons, wax, about 20 feet of string, and a nail or ice pick.

Procedures:

1. Make a small hole in the center of the bottom of each container with the nail or ice pick.
2. Wax the string by running it over the wax several times.
3. Thread one end of the string through the bottom of one of the cans and out through the top. Fasten it to a button, or tie a large knot, to prevent the string from being pulled back through the hole.



4. Do the same thing with the other can.
5. Have a "fellow physicist" take one of the cans to the other end of the room or into the next room. Be sure that the string is taut and does not touch anything. This experiment works even better out of doors where there are no walls to reflect the sound of your partner's voice.
6. Have your partner talk into one can while you place the other to your ear.
7. Talk back and forth with this can telephone.

Explanation: When you speak into one of the cans, you cause the air in it to vibrate. The air in turn causes the bottom in the can to vibrate. This action sets the cord into vibration. The vibrations are sent to the other can by way of the waxed string. The other can starts to vibrate, which causes the air in it to vibrate. The vibrating air is interpreted as sound by the brain of the receiver.

Stand so that the string touches some object midway between the two cans while a conversation is in progress. Account for what happens.

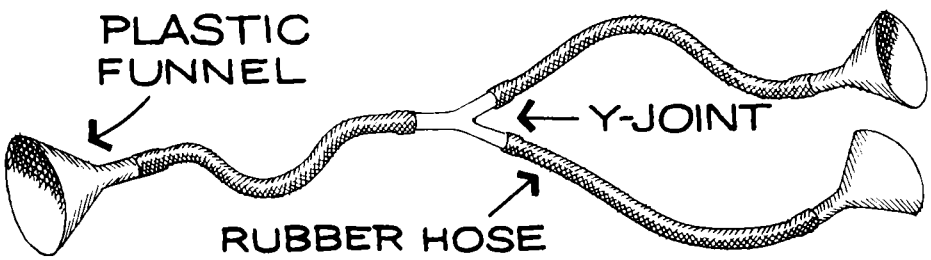
Experiment 34 Making a stethoscope

Materials: Three plastic funnels with short stems, Y-joint glass tubing, string, and three pieces of thin rubber tubing, each about 10 inches long.

Procedures:

1. Fasten the pieces of rubber tubing to each of the three arms of the glass Y-joint with string or rubber bands. Moisten the glass before trying to slip the rubber tubing over it. (If you can get just two funnels and have no Y-joint, you can still make a stethoscope for one ear only.)
2. Using a circular twisting motion, insert the stems of the funnels into the other ends of the rubber tubing.
3. Place two of the funnels over your ears. Place the other funnel over a friend's heart and listen.

Explanation: The air inside the funnels makes the vibrations of the heartbeat easier to hear. In this experiment the sound is produced by a solid vibrating. The solid is the heart. These vibrations cause the air in the funnels to vibrate. Finally, by means of the eardrums and nerves, the vibrations reach the brain, which interprets them for us as heartbeats.



5

LIGHT

WHAT IS LIGHT?

In this chapter we shall discover many interesting facts about light.

Scientists do not know exactly what light is. Some believe that light is made up of tiny particles called photons. When these particles enter the eye they produce a feeling, or sensation, which we call sight, or vision. Others believe that light comes in continuous waves. All scientists agree, however, that light is a form of energy, that it can do work, and that we depend on it.

Stop! Close your eyes for several minutes. Try moving around. Imagine living like this the rest of your life — without light. We have become so accustomed to having light that we take it for granted.

Your eyes need light in order to see, of course, but many of man's most useful instruments need light to operate, too: microscopes, telescopes, cameras, and motion picture projectors all depend on light. With the aid of light, scientists can study the tiny germs that cause diseases. Astronomers are able to study the entire solar system with telescopes. Light rays make possible photography and motion pictures of people, places, and things.

Light is still more important in other ways. Our vegetable foods cannot grow without the energy of sunlight. All living things depend on the food that plants make, or on other living things that eat plant food. Man depends on both plants and animals for his survival. Wood, coal, oil, tar, and many other common products are all derived from growing things and therefore could not exist without sunlight. It is one of our very important basic sources of energy.

How light travels

If a friend stands in another room and calls out your name, you can hear him, but you cannot see him, unless mirrors are used. This is because light travels through air only in straight lines called rays, while sound travels in a spherical wave front and reflects so that it goes around corners.

We make use of the principle that light travels in straight lines when we make shadow pictures. The light rays cannot go through an opaque object like a hand. Because the hand stops part of the beam of light, dark spaces of the same shape as the hand appear on the wall or screen.

The experiment we performed to show that sound does not travel through a vacuum shows also that light does travel through a vacuum. In that experiment we were able to see the bell in the jar because light rays traveled through the vacuum and were reflected from the bell to our eyes.

A third important fact about the traveling of light is

its speed. Experiments show that light travels at a speed of more than 186,000 miles per second. This means that light can travel around the earth, at the equator, about 7½ times in one second. It can cover the 93,000,000 miles from the sun to the earth in a little over eight minutes. If you were riding on a photon, how many round trips could you make between your home and school in one second? But it takes light several years to reach the earth from even the nearest stars.

Reflection

Throw a tennis ball straight down. It bounces straight up. Throw the ball at an angle and you will notice that it will bounce up at an angle, but away from you. Throw it against a very rough surface — such as a gravel driveway — and you will notice that it bounces back in one of many possible directions. Light rays behave in a similar way.

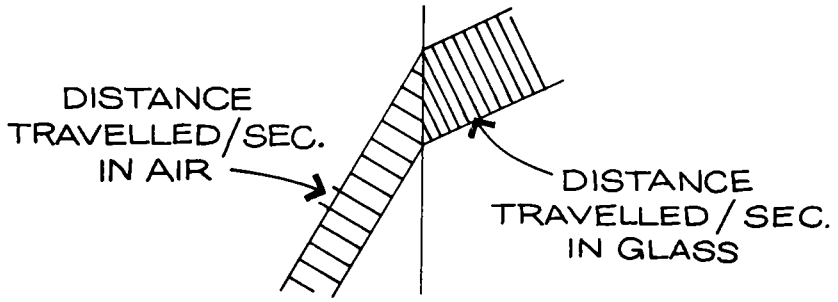
When you shine a beam of light directly at a flat mirror, the rays are reflected right back to the flashlight. When you shine a beam onto a mirror at an angle, the rays are reflected at a slant, but in the opposite direction. Should you shine the beam on an irregular surface the rays would be reflected in many different directions. The resulting light is called diffused light.

We can define reflection as the bouncing back of light from any object it hits. We see only those objects that are able to reflect light to our eyes.

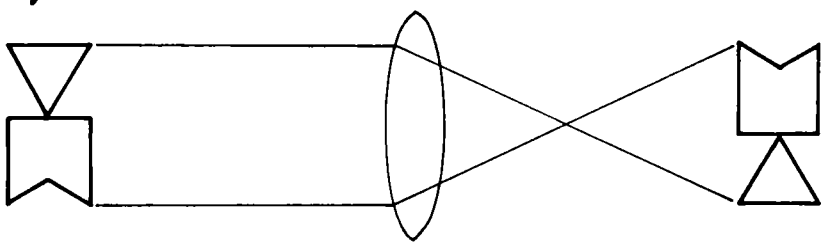
Refraction

When light passes from a less dense medium (say air)

to a more dense medium (say glass or water), it slows down a little. If a beam of light strikes a piece of glass at an angle, one side of the wave front of the beam will slow down before the other side and the beam will therefore be bent toward the denser medium, as the diagram shows.



Refraction explains all sorts of light phenomena, such as the effect of wearing lenses (we call them eyeglasses). Lenses are curved pieces of glass that bend the rays of light which pass through them. This bending is called refraction. Refraction of light means the bending of rays of light when they pass at a slant from one transparent material into another one of different density.



There is a convex lens right in your eye that focuses the reflected rays from an object on the retina, or screen, of the eye. The image on the retina is inverted,

but your brain interprets the image correctly so that the world doesn't look upside down.

An ordinary magnifying glass is another example of a convex lens. You can understand how light is affected by a convex lens if you perform this experiment:

1. On a sunny day hold a convex lens in front of a window. Then hold a piece of paper behind the lens at a distance of about three feet.

2. Move the paper farther from and then closer to the lens and observe what happens. This motion is called focusing, and the point where the image is sharpest is called the focal point. You will observe also that the image is inverted. You can see how this happens by looking at the diagram.

What is color?

As stated at the beginning of this chapter, light seems to move in bundles of energy called photons, and also in waves. Like radio waves, light waves have different lengths, and it is this difference in wave lengths that causes the different colors that we see. The longest light waves that we can see are violet and as they get shorter they change to indigo, blue, green, yellow, orange, and red.

Objects have color because they reflect only certain wave lengths of light. A red sweater, for example, reflects only red light, a yellow flower only yellow light. All other wave lengths of light are absorbed.

A beam of white light contains all the wave lengths, and it is possible to show this by spreading out a beam

of sunlight with a triangular lens called a prism. (We shall do this in Experiment 41.)

Perhaps you have seen a small rainbow in the spray of the hose while watering a garden. You learned that the rainbow always appears in the opposite direction from the sun. Your garden rainbow works on the same principle as the rainbow in the sky.

A rainbow is made when sunlight shines through drops of water in the air. Each raindrop acts as a prism. As white light travels through the drops of water, it is refracted in such a way as to separate various wave lengths of light that are in white light. Each band of light of a certain wave length is seen by us as a color — violet, indigo, blue, green, yellow, orange, and red. For this reason, scientists say that white is not a true color but is composed of many wave lengths which can be separated into several colors.

Let us now obtain more information about light by doing several experiments.

Experiment 35 Light travels in a straight line

Some things often appear to be so obvious that it doesn't seem necessary to prove them scientifically. But it's better to set up a proper test anyway. After all, it seemed *obvious* for many years that the earth was flat and that the sun went around it. This experiment gives definite evidence that for all practical purposes

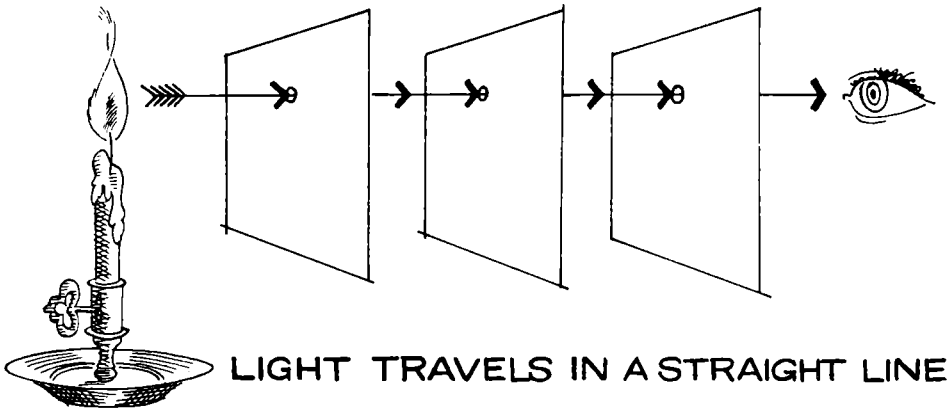
light travels in a straight line. It is necessary to say "for all practical purposes" since it now seems that over vast reaches of outer space, light rays sometimes actually do bend a bit.

Materials: A candle, a dish, a yardstick, three pieces of thin cardboard or manila folder, and three small supports for the paper.

Procedures:

1. Cut three identical pieces from the cardboard or manila folder about 4 x 5 inches.
2. Place the three pieces together and punch a hole about ⅛ inch in diameter in the center of the three cards.
3. Make three identical supports for the cards from wood blocks or heavy cardboard. Arrange the cards on the table as shown in the diagram. Be sure the holes are the same height from the table top.
4. Light the candle, soften the bottom by heating it, and attach it to a dish.
5. Place one of the cards about a foot away from the candle and sight the candle flame through the hole. Now place the second card a foot away from the first. Adjust it so you can see the flame through both holes. Do the same with the third card. The two holes must be lined up in a straight line.
6. Move any one of the cards about one-half inch to a side. Can you still see the flame through the holes?

Explanation: Once one of the cardboards is moved a short distance from its original position, it is impossible



LIGHT TRAVELS IN A STRAIGHT LINE

to see the flame through the holes. This is due to the fact that light travels in a straight line.

Sound vibrations, if the candle produced any, could be heard from behind the cardboards because sound reflects readily from many surfaces.

Experiment 36 Fun with mirrors — reflection

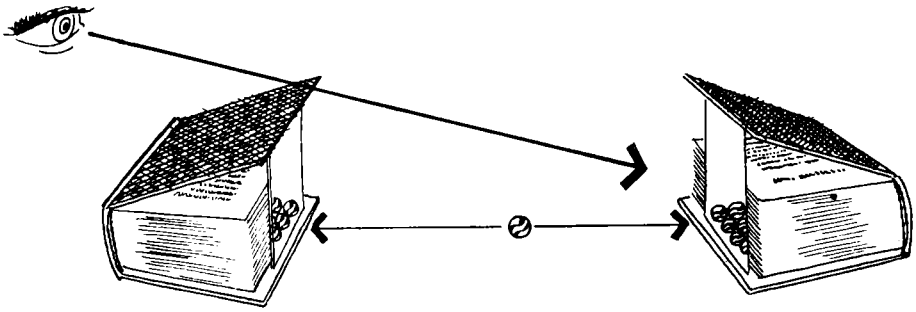
A mirror is a smooth surface that reflects all, or almost all, of the light that strikes it. Most common mirrors are made of glass with a metallic coating on the back. A quiet pond or a highly polished piece of metal, however, may also act as a mirror.

No doubt you have played with mirrors many times. You may have seen your figure changed when you looked in various types of mirrors: in one you were fat and short and in another you appeared skinny and tall. Let us learn a few things about the properties of mirrors by performing the following five parts of this experiment.

Materials: A clock, two small mirrors, Scotch tape, a book, a coin or marble, some sheets of paper, carbon paper, and a sheet of metal with a high polish.

Procedures:

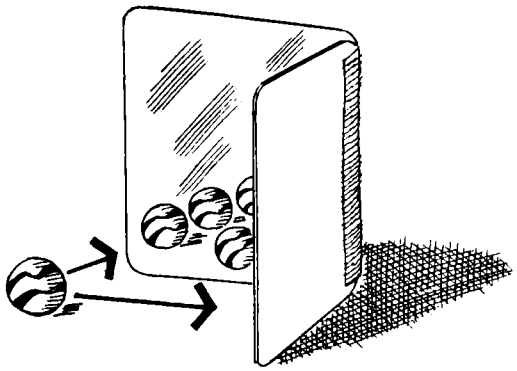
PART A. Stand two flat mirrors on edge in such a way that they are parallel to each other. Have them face each other. You may want to support them by placing them between pages of a book. Now place a coin or a colored marble between the mirrors. Look over one mirror into the other. You will see many coins or marbles. This is so because the light from the coin or marble is reflected back and forth many times. Of course, if you put a half dollar there you will, unfortunately, still have merely a half dollar, but many images of it!



PART B. Hinge two mirrors together using flexible tape. Set them at a right angle to each other. Next place a coin between the mirrors as shown in the diagram. Count the number of images of the coin. Change the angle between the two mirrors, making it smaller and smaller. What is happening to the number of images of the coin? Now move the mirrors so that the angle

between them is greater than a right angle. What is happening to the number of images of the coin?

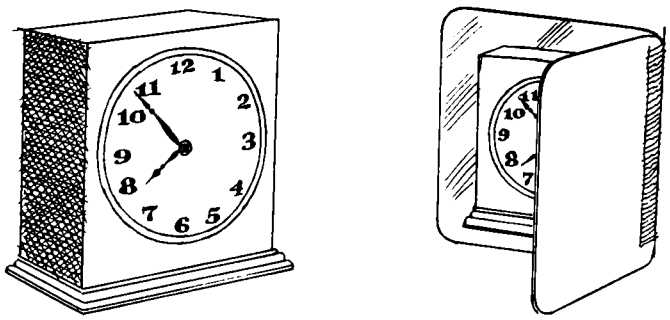
When you begin to move the mirrors toward each other, you first see a reflection of the coin in each mirror. Then, as you move the mirrors closer together, you begin to receive reflections in each mirror of the reflections in the other mirror. The closer the mirrors come together, the more images you see, and the farther apart the mirrors are, the fewer images of coins you are able to see. You may have noticed that some of the images are brighter than others. This is because the more times an image is reflected, the dimmer it becomes. Some of the light energy is used up during each reflection.



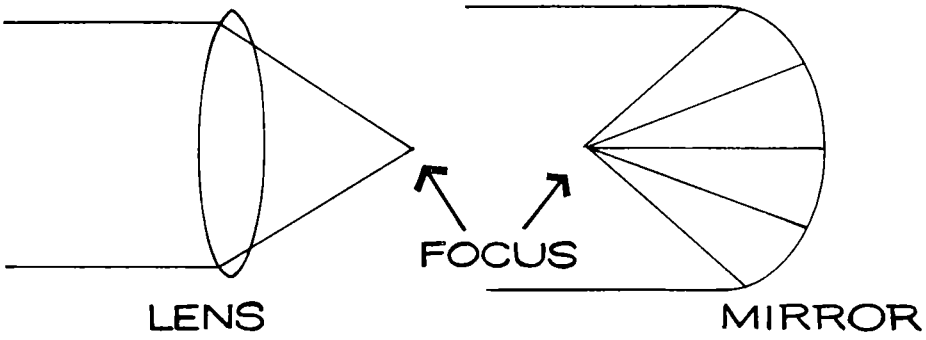
PART C. Write your name on a sheet of white paper. Bring it in front of a mirror. The writing is reversed. Place a sheet of carbon paper *with the carbon side up* under a sheet of white paper. Again write your name on the paper. When you hold the paper with the side that has the signature in carbon in front of the mirror, you will notice that the writing is reversed — but reversed in such a way that the signature comes out in

the right way. This reversal is because the writing in carbon was reversed originally, and the mirror reversed it again. Thus it came out in the original position.

PART D. Look at the face of a clock in a mirror and see if you can tell what time it is. As expected, you have a bit of trouble. Now try this: Place the clock in front of two mirrors, as you did the coin in Part B. The numerals are no longer in reversed position. The reason for this is that the clock has been reversed twice. The light from one half of the face goes to the left mirror, is reflected to the right mirror, and then back to your eye. The light from the other half of the face goes to the right mirror, is reflected to the left mirror, then back to your eye. The image is reversed once in each mirror — twice altogether. Consequently, you see the face in the original position.



PART E. Take a metal sheet (about 6″ by 12″) that is thin and highly polished. A ferrotype plate that is used in photography for drying prints is excellent. Or you may want to try using aluminum foil smoothed over a piece of cardboard. Look into it. Your image appears in it just as it does in a silvered glass mirror. Now bend



the ends of the metal sheet toward you so that the center of the sheet curves away from you. Hold the sheet vertically and look into it. Do you like your long and thin face? Next, hold the sheet horizontally and look into it. Do you prefer your short and fat face?

Just for the fun of it, try this: Bend the sheet so that it curves toward you and look into this curved mirror vertically and horizontally. Don't be alarmed at what you see. It is still you. Try looking at yourself in a highly polished coffeepot or in the bowl of a tablespoon, one surface at a time.

When you bend the metal plate so that the curve is away from you, you form a concave mirror. When it is held vertically, the image formed is thin and long. But when the same mirror is held horizontally, the image becomes short and fat. Such are the reflections from concave mirrors.

The other mirror you formed was a convex mirror. When it is held vertically, the image in it appears short and fat. When light rays are reflected from a flat surface they show an image in exactly the same size as the object. When the surface is bent, the light waves are

reflected in different directions so that different parts of the object seem to be larger or smaller than they actually are. In fact, it is possible to focus light rays with a bowl-shaped mirror in much the same way as they are focused by a convex lens, and many astronomical telescopes are made with such mirrors.

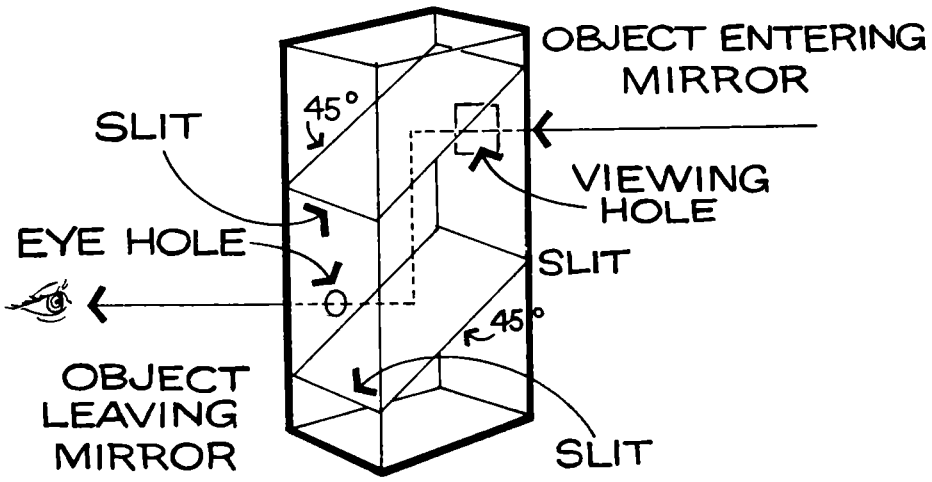
Experiment 37 Making a periscope

Let us use the principle of mirror reflection in the construction of a periscope.

Materials: A rectangular milk carton, two flat mirrors, cellulose tape, and a sharp knife.

Procedures:

1. With a sharp knife, slit a hole on each end, but on opposite sides, of the milk carton for the mirrors to fit through. See the diagram.
2. Insert a mirror in each slit with the polished surfaces facing each other. Fasten the mirrors with tape. Adjust them at about 45° angles.



3. Hold the periscope so that one end is below the edge of the table, and look over the top of the table. It may be necessary to make additional fine adjustments.

Explanation: The light rays that strike the upper mirror are reflected, or bounced, toward the lower mirror. From the lower mirror the light rays are reflected to the eyes.

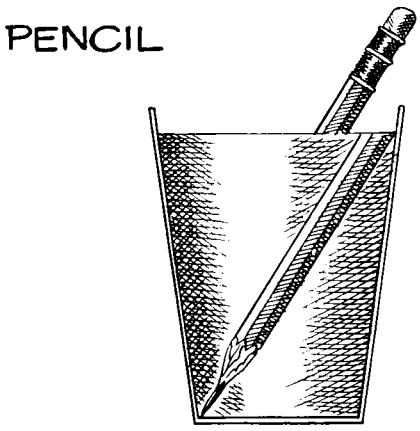
Experiment 38 Why a pencil appears broken when in water

On numerous occasions, such as while drinking pop through a straw, or while stirring tea with a spoon, you may have noticed that the straw or spoon appeared broken at the point where it came in contact with the liquid. Of course, upon examination you learned that such was not the case. This apparent break can be illustrated and explained by this experiment.

Materials: A long pencil, tall glass of water, and food coloring.

Procedures:

1. Fill the glass with water almost to the top and put a pencil or a glass tube or a spoon obliquely in the water.
2. Look at the part of the pencil that just touches the water. Look at the other parts of the pencil submerged in the water. Record your observations by *drawing* the results in your lab notebook.



3. Add a little food coloring to the water. Do you notice any difference?

Explanation: The pencil appears broken at the point where it touches the water. The rays of light that come to the eyes from the upper part of the pencil go only through the glass and air. They are not bent, but are merely reflected. The light rays that reach the eyes from the part of the pencil just below the level of the water pass through the glass, the water, and the air. Those parts of the rays that pass through the water are slowed down so that actually the image of that part of the pencil that is under water reaches the eyes just a bit later than the image of the part that is above the water. The difference in time is great enough to cause a distortion. We call the bending of light as it passes slantwise through two transparent materials *refraction.*

If you put your hand under the water and try to touch the pencil where it appears to be, you will learn that it is not there.

The part of the pencil under the water appears larger because both the water and the curvature of the glass

act as magnifiers. Observe what happens to the size of your hand when placed in a large glass pitcher or bowl of water.

You can make this experiment more spectacular by adding a few drops of food coloring to the water.

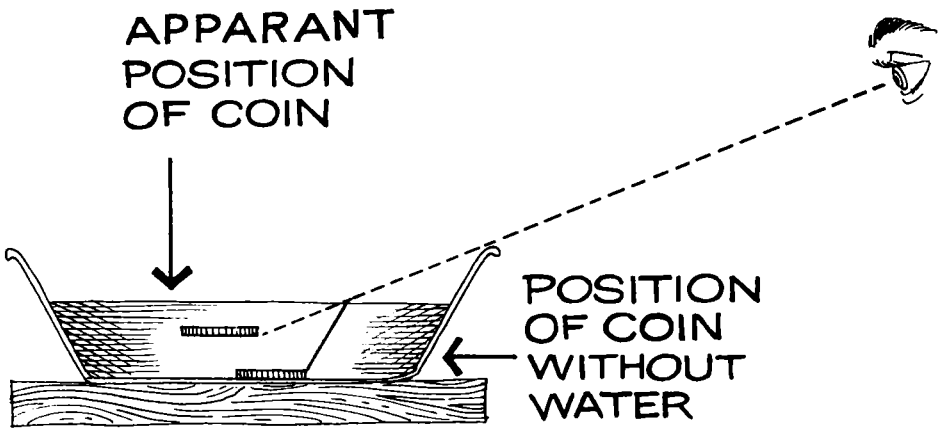
Experiment 39 The disappearing coin — reflection and refraction

In this experiment we shall make an invisible quarter appear with the help of refraction and reflection.

Materials: A quarter, a pan, and water. A friendly observer is also needed.

Procedures:

1. Place the coin in the bottom of the pan near its edge. Ask your friend to come close enough to the pan so that he can see the coin over the edge of the container. Now ask him to step back so that he *just barely* sees the coin. Ask him to maintain this position.
2. Begin pouring water into the pan. Pour it very slowly to avoid shifting the position of the coin.
3. Your friend will see the coin reappear gradually as water is added to the pan. The more water that is added, the farther out the coin seems to move.
4. Have your observer maintain the same position while you siphon the water out of the pan. What happens?
5. Repeat the experiment, exchanging places with your friend.



Explanation: When no water was in the pan, the light passed from the coin to your eyes in a straight line. When you backed away, only a very small part of the coin was reflecting light to your eyes. As water was poured into the container, the water bent (refracted) the light rays. They were bent at such an angle that the light reflected from the coin again entered your eyes.

Experiment 40 Focusing a beam of light without a lens

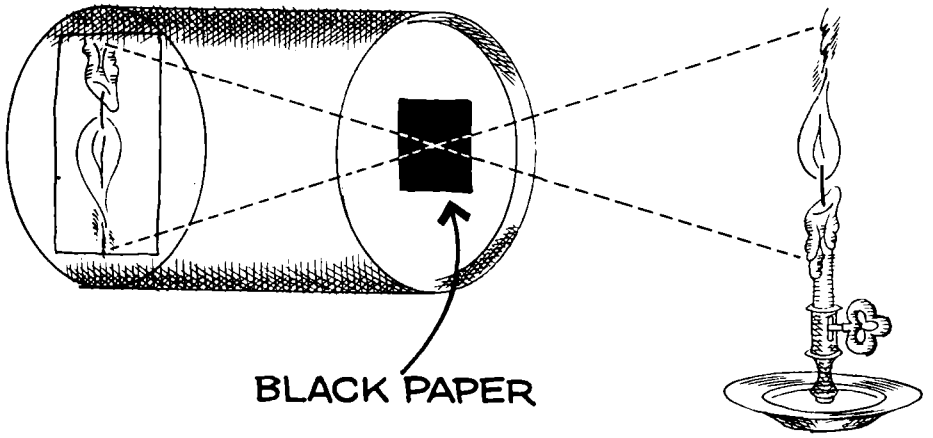
Most of us have taken our first pictures with a box camera. It is a lightproof box with a small opening at one end and a sensitized film at the other. Let us make a simple camera, using the knowledge about light that we acquired in the previous experiments.

Materials: A cylindrical cereal box, a thin piece of black paper about 2″ square, a piece of waxed paper about 3″ square, a needle, and a candle.

Procedures:

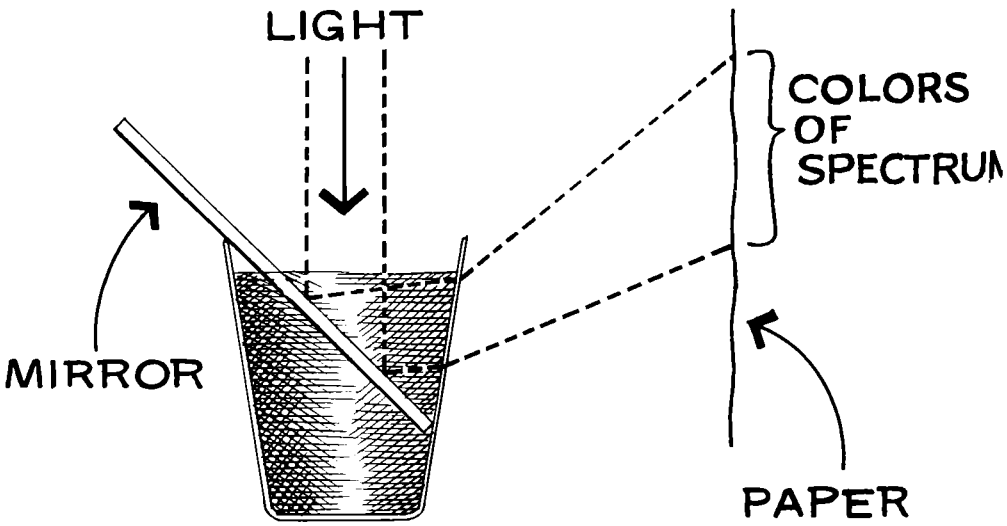
1. Cut a hole about the size and shape of a postage stamp in the center of one end of the box. Paste the black paper over this hole. Punch a small hole in the center of the paper with the needle.
2. In the other end of the box cut an opening about two inches square. Paste the waxed paper over this opening.
3. Darken the room and hold the end of the box with the pinhole about three or four inches away from a burning candle. Focus it by moving either the camera or the candle back and forth until a sharp image shows on the waxed paper.
4. Observe what you see on the waxed paper. Make a drawing of this in your lab notebook.

Explanation: Light from different parts of the candle, or from other illuminated objects, travels in a straight line through the pinhole. The pinhole acts as a very small lens. The image formed on the waxed paper is inverted.



Experiment 41 Taking white light apart

In 1666, Isaac Newton, an outstanding scientist, held a triangular piece of glass, called a prism, in a beam of sunlight. To his astonishment, he observed that the white beam was separated into red, orange, yellow, green, blue, indigo, and violet. After several additional trials, he concluded that white light must be a combination of the above colors. It is possible for us to repeat his experiment even though we may not have a prism.
Materials: A shallow, clear drinking glass, a pencil, and a flat mirror.
Procedures:
1. Fill the glass with water and place in it a mirror at an angle of about 45°. Only about half of the mirror should be in water.
2. Place the glass and the mirror in strong sunlight in such a position that the rays will hit the mirror and produce the seven colors on a sheet of paper or on the



wall. This will require experimenting to get the correct positions.

3. Stir the water gently with a pencil and watch the results on the wall. Repeat this part several times.

Explanation: The beam of white light passes at an angle from the surface of the water to the air. That edge of the beam that hits the air first is able to go faster and therefore gets a head start over the other edge. As a result, the beam is spread out so that when the various wave lengths that make up white light hit a flat surface, the different colors are reflected.

When you stir the surface of the water, there is no straight edge to give one edge of the beam a head start over the other so that the various wave lengths recombine and the light appears white again.

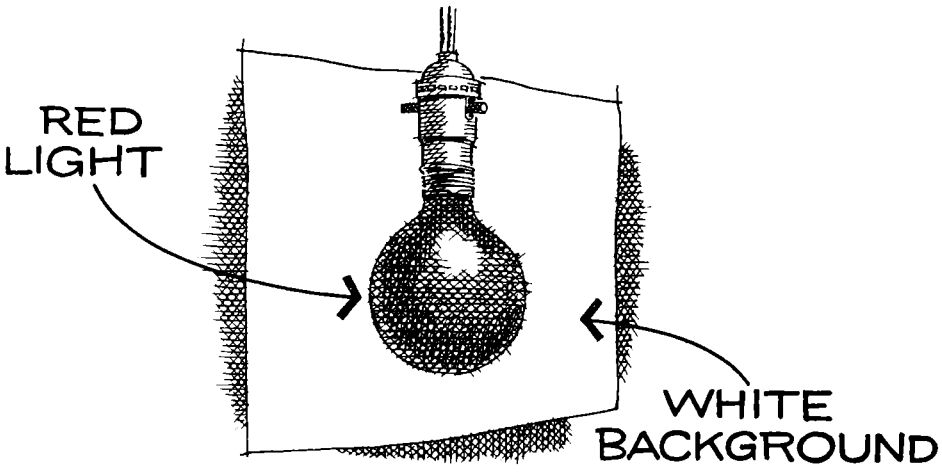
Experiment 42 Seeing green after you see red

Here is an experiment on colors that will amaze your friends. It is one that is a little more difficult to understand, but you will have fun doing it.

Materials: A red light bulb, a white screen or sheet of unlined white paper, and a socket and extension cord for the bulb.

Procedures:

1. Hang the bulb in front of the screen or sheet of white paper, and then turn on the electricity.
2. Look at the glowing bulb for about three minutes. Stare at it.



3. Turn the bulb off, and continue looking at the screen. What color do you see about the bulb?
4. On some other day, or later in the same day, repeat the above steps using different colored bulbs.

Explanation: After you stared at the red light, your eyes became tired by the color and they no longer responded to the red wave-length. As you looked at the white background, your eyes recorded the white light with the red subtracted from it. This produced a sensation of green. Any two colors which produce white light when combined are said to be complementary colors. After you looked at red you saw green because green is the complementary color of red.

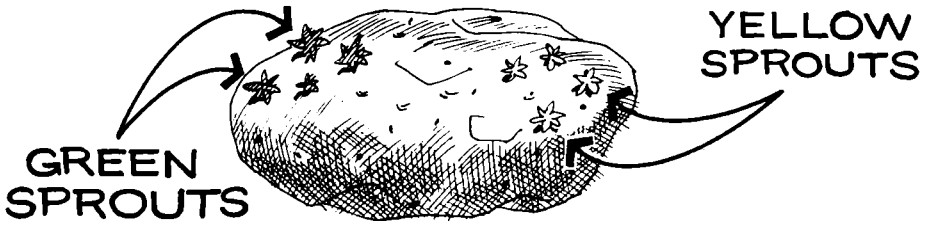
The person who must stare longest to produce these results is the one whose eyes are the strongest. A person with weak eyes will need to stare only a short time.

If you cannot obtain colored bulbs, you may use squares of brightly colored paper. They should be placed in the center of a white background and brightly lit.

Experiment 43 Plants need light for proper growth

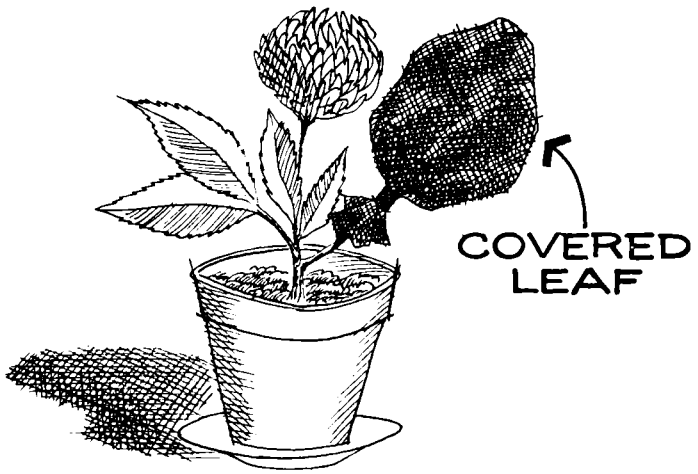
Light, as a form of energy, is needed by most plants. In addition to supplying heat for plants, it also makes it possible for them to manufacture chlorophyll, the green pigment. You can show this by performing two simple experiments.

PART A. Select a potato that has started to sprout and put it in a dark, warm place. The potato will continue to sprout, but the sprouts will be pale yellow instead of green.



Later, place the potato in sunlight and notice the gradual change in color of the sprouts.

PART B. Cover one of the green leaves of a healthy geranium with black paper. Tape the edges so no light gets in. Keep the plant this way in sunlight for about a week. Be sure to water it regularly.



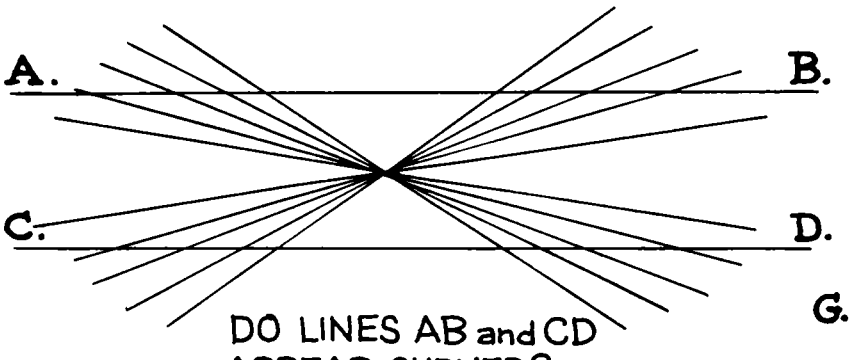
After about a week, remove the paper and observe the coloring of the leaf. If the results are not satisfactory, cover the leaf again and this time let it stay covered for two weeks.

Explanation: Plants are unable to manufacture chlorophyll without sunlight. The main food factory of the common plants is the leaf. Its wide surface enables the leaf to absorb large amounts of sunlight. The sunlight also supplies the energy needed by plants to change water and carbon dioxide, with the help of chlorophyll, to sugar. This process is called photosynthesis.

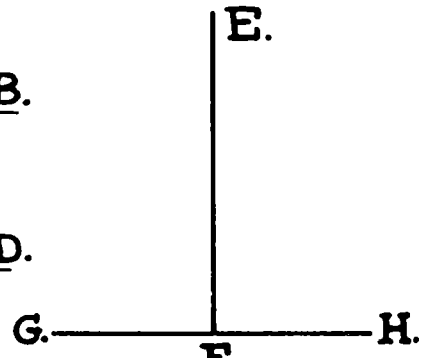
Experiment 44 Some optical illusions

Light, with its many interesting properties, can play tricks with our eyes. We call these optical illusions.

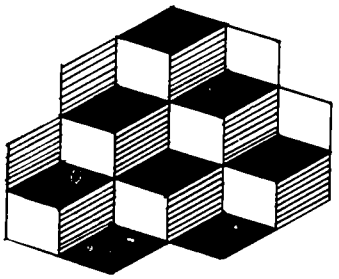
Draw the following diagrams on a larger scale and try them on your friends.



DO LINES AB and CD APPEAR CURVED? PLACE A RULER ALONG THEM.



WHICH IS LONGER EF or GH ? MEASURE THEM.



HOW MANY BLOCKS ARE THERE, SIX OR SEVEN? STARE AT THEM FOR A FEW MINUTES AND THINK OF NUMBER OF BLOCKS YOU DID NOT SEE AT FIRST. COUNT THEM AGAIN.

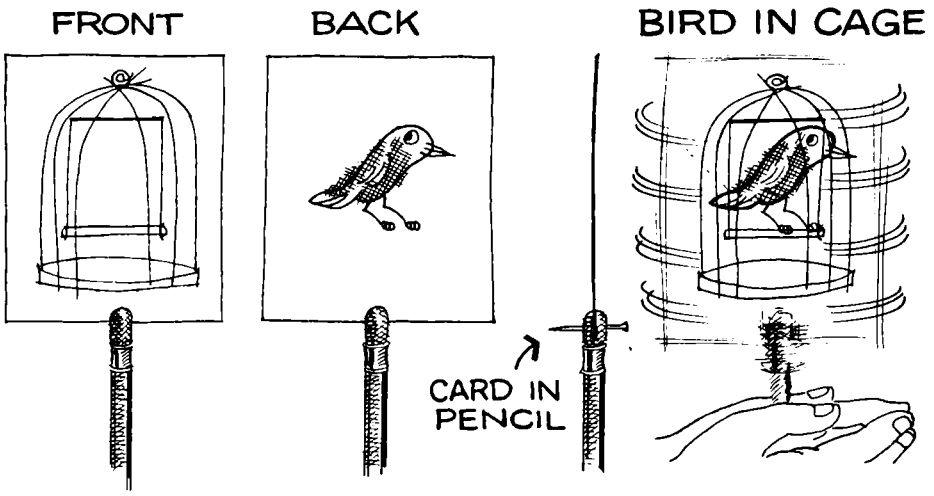
Why we see "still" pictures "move"

No doubt you know that the motion pictures are actually made up of a series of "still" pictures. You can demonstrate the principle involved in motion pictures by performing this experiment.

Materials: A pencil with an eraser, a sharp knife or razor blade, a straight pin, a white card about 2″ square, and a colored pencil.

Procedures:

1. On one side of the card draw a bird cage and on the other side draw a bird. Color the bird.
2. Slit the eraser of the pencil down the middle as far as you can. Of course you are not to slit your fingers!
3. Insert the card in the slit and fasten it by pushing a pin through the eraser and the card.
4. Roll the pencil back and forth quickly between the palms of your hands.



5. Observe what happens as you change the speed with which you twirl the pencil and the card.

Explanation: When you twirl the card fast enough, you see the bird for less than 1/16 of a second. Before the end of this time, the cage is in view. Since the image of the bird on the retina of your eye and the nerves connected with it persists until you see the image of the cage, the bird appears to be inside the cage.

A motion picture projector sends separate pictures to the screen at a rate of 24 "still" frames per second. The image of each picture, which is a bit different from the one before, stays on the retina (or the nerves connected to it) until the next picture gets there. This gives us the sensation that the picture is continuous and in motion.

Experiment 45 Making fire with ice disks

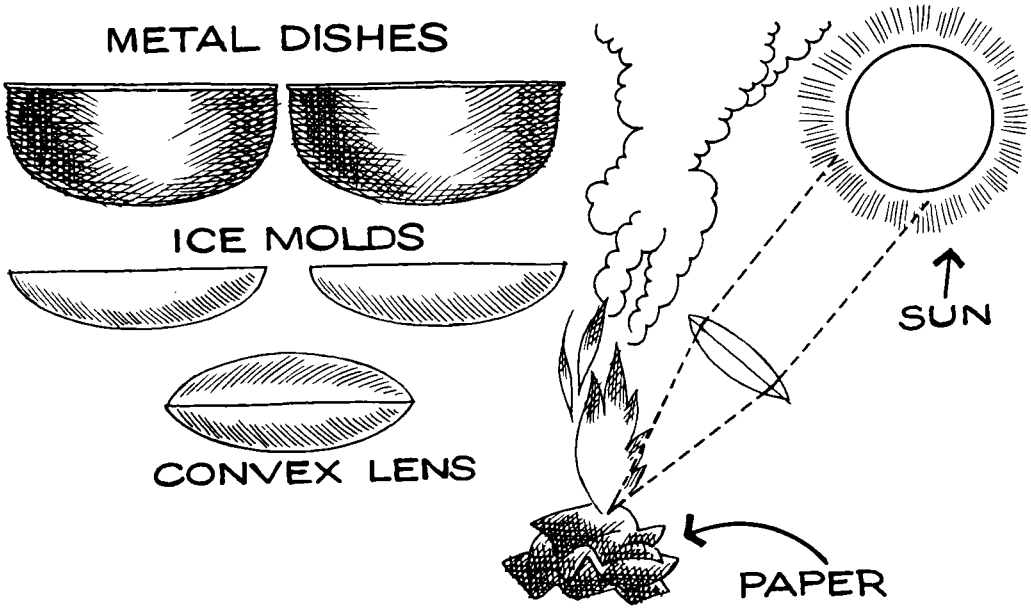
We have done several experiments, to this point, that seem to have a touch of magic. This one tops them all.

We can make a fire with ice because of several principles of light and lenses.

Materials: One or two metal dishes with rounded bottoms.

Procedures:

1. Take a metal dish with rounded bottom and fill it about half full with water that previously has been boiled to expel the dissolved air. The less air in the water the better. Freeze the water in a refrigerator. Now remove the spherical segment of ice from the dish with the aid of water. Wrap the disk in some paper towels and place it back in the freezer.
2. Make a second disk following the steps given above.
3. Take a warm iron and pass it over the larger, flat surface of each disk to make them fit well when placed face to face.
4. Mold the two disks of ice with your hands so that you have but one convex lens.



5. On a bright, sunny day, take the convex lens outdoors and have the sunlight pass through the center. Focus the light onto a piece of crumpled porous paper, one with a low kindling temperature. If you did the experiment correctly and the ice lens is very clear, the porous paper should at least char.

Explanation: When you placed the two pieces of ice together, you formed a double convex lens. Light that passes through the center of such a lens will come to a sharp focus — on the paper in this case. The concentration of light rays on a small area produces sufficient heat to cause the paper to char. The ice disk works on the same principle as a magnifying glass.

6

STATIC ELECTRICITY

HAVE YOU ever been hit by a flash of lightning? No doubt your answer is that it's impossible to be struck by lightning and live to tell about it. Well, you are wrong. You and I have been struck by a form of lightning many times. Try this. On some cold, clear, dry day, shuffle your feet across a thick rug, then touch a person or a piece of metal. A spark will jump from your finger to the other object. You will receive a little shock from this very small flash of "lightning." You may even see the spark if you perform the experiment in the dark. By rubbing your feet over the rug you have generated static electricity. *Static electricity is a form of electric energy produced by rubbing together certain types of different materials.*

Lightning is the result of an accumulation of electric particles in the clouds. These particles are called electrons. When the number of electrons on a cloud becomes large enough, they tend to jump from one cloud to another, or from the cloud to the earth. Some experimenters have claimed that electrons rush from the earth to the clouds, which temporarily have a shortage of electrons. The direction, however, is not important for our experiments. A spark or flash of lightning is

the same as the tiny spark you made after you shuffled across the rug or noticed while combing your hair. The lightning from the clouds, however, has billions more electrons than the small spark from the comb.

What happens when you comb your hair? The movement of the comb through your hair causes the electrons from your hair to collect on the comb. When the number of electrons on the comb is great enough, electrons jump from the end of the comb back to your hair. Thus a flash of lightning from a cloud has the same cause as a spark (little lightning) from a comb.

Before we can perform experiments with static electricity with understanding, we need to look at some of its other properties. We shall start by reviewing the make-up of an atom. As we said before, an atom is very small — so small that it cannot be seen. Every atom, in turn, is composed of smaller parts which are called neutrons, electrons, and protons. Electrons have a negative charge; protons a positive charge; and neutrons have no charge. The neutrons and protons are in the center, or nucleus, of an atom with the electrons moving about the nucleus. (There are some models of atoms on pages 176 and 177.)

Substances that have an equal number of electrons and protons have no electrical charge and are referred to as being neutral. The nucleus of an atom remains the same under most circumstances, but the electrons whirling around it can be knocked out of their orbits. For example, some force such as rubbing can either

cause electrons to leave the neutral substance or bring extra electrons to it.

If, during the rubbing, electrons are removed from an object, the object then has more protons than electrons. It is said to be positively charged. If electrons are added to a material, the material then has more electrons than protons. Such a material is said to be negatively charged.

Let us see if we can understand this better by considering a pair of scales. On one side there are six black checkers. These represent the protons in the nucleus. On the other side are six red checkers. They represent the electrons. The scale is balanced and the atom is neutral. Now knock off one of the red checkers. This will leave an excess of black checkers. The black side of the scale will drop down. The pair of scales will no longer be in balance, or neutral, but will be "positively charged."

If on the other hand, you add an extra red checker, the electron side will drop and the system will be "negatively charged." In either case, the sides have moved away from their balanced, neutral position. In the same way, electrically charged objects are not as balanced or stable as neutral objects.

When an object is electrically charged, the charge itself is concentrated on the points or ends of the object. So remember — for best results in the following experiments, bring the end of the charged object near the other substance.

An object may remain electrically charged for a period of time if it is an insulator. Insulators are substances which do not permit electrons to move along or through their molecules with complete freedom. Some of the common insulators are glass, silk, nylon, wool, hard rubber, and wax.

Some common places where static charges are found

Static charges are found in many places and must be guarded against. While riding along in a car, you may have noticed a chain dragging from a gasoline truck. Perhaps you thought that the driver forgot to tie the chain to the proper place. This is not so. The dragging chain serves a vital purpose. It permits the static charges to travel from the truck to the pavement. The charge is developed by the rolling tires. This method of getting rid of static electricity prevents a spark from igniting the gasoline vapor. Recently, trucks have been using special tires that help to ground static charges.

In industries such as flour mills or gasoline refineries, machines are grounded to prevent sparks. Dangerous quantities of static electricity are generated on conveyor belts, printing presses, or on wide pulleys. These charges may become great enough to produce a spark which might ignite the fine dust or the vapor and thus cause a dangerous explosion. Such explosions have happened on many occasions.

As you approach a toll booth on a turnpike, your car will travel over a flexible metal rod in the middle of the

road. This rod touches the axles on the car. By this method the static charges on the car run harmlessly down the rod into the ground. Neither the driver nor the toll collector experiences an electric shock when the money passes from one to the other.

Charges of static electricity may accumulate on our clothing. Some of the materials that collect static charges are silk, wool, nylon, and rayon. If you take off too quickly a shirt or a dress made from one of the above materials, you will charge it. You may even see sparks jump if you do this on a dry day in a dark room. Try doing this in front of a mirror at night.

Clothes made from the above materials should never be washed in any flammable liquid — not even where there is ample air circulation. Static electricity will collect on these materials during the rubbing process. A spark could jump from the material to the rim of the metal container and thus ignite the vapor and the liquid. If a fire started you might be burned seriously.

Experiment 46 Producing static electricity

Benjamin Franklin, by his famous kite experiment, was one of the first to show that static electricity is present in the clouds. One stormy night in 1752, he and his son flew a kite with a metal key attached to the lower end of the string. The kite became charged with static electricity which flowed down the wet string to

the key. Franklin and his son were very fortunate that they were not killed during their experiment.

Not much was known about the nature of electricity in Franklin's time, but only a fool would try to repeat such an experiment in the light of today's knowledge.

You can, however, make static electricity by using several different materials, and the charges you obtain will be of the same nature as those obtained by Franklin. But yours will be neither as powerful nor as dangerous.

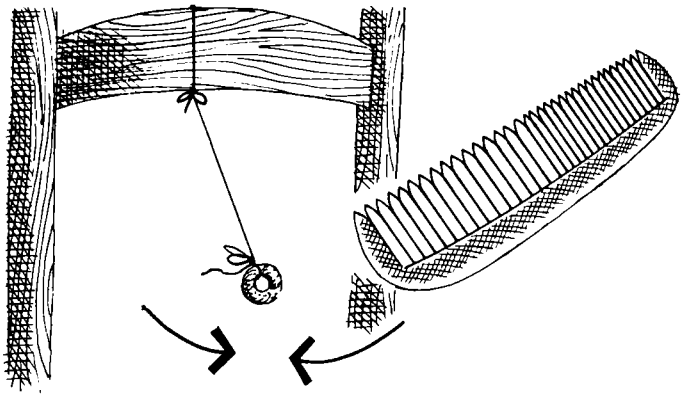
In each of the following parts, static electricity will be produced by friction. Keep in mind that best results can be obtained when the hair — and weather — are dry. On humid days the charges travel from the comb into the fine water droplets in the atmosphere.

Materials: A hard rubber or nylon comb, unsweetened dry cereal (puffed rice would be best, but if it is not handy, small bits of tissue paper will do), fine thread, a pinch of fine, dry sawdust, an egg, and a pencil.

Procedures:

PART A. Wash a comb with warm, soapy water to remove any oil that may be on it. Pass the comb through a heavy crop of dry hair — your own or a friend's — and bring one end of the comb near a suspended grain of puffed cereal. If you haven't a heavy crop of hair, you can rub the comb briskly with a piece of wool.

Allow the cereal to remain in contact with the comb for a few minutes. After the cereal jumps away from the end of the comb, try bringing the comb near the



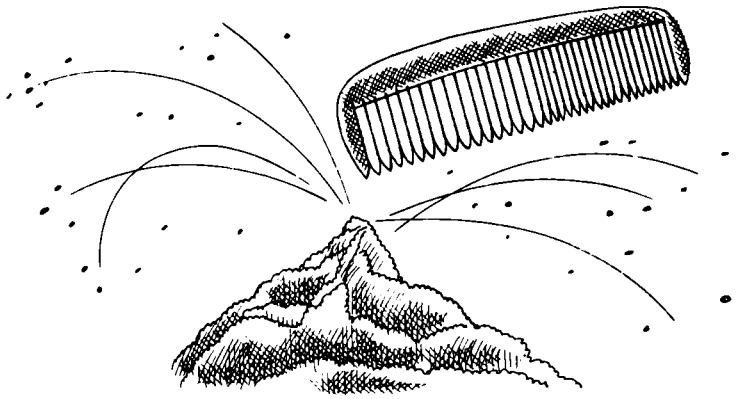
cereal again. The cereal will run away from the comb. Touch the cereal with the tip of your finger, and again bring the charged comb near it. The cereal will be attracted again to the comb.

Explanation: When the comb was passed through the hair, it picked up many electrons from the hair. The molecules in a strand of hair have many atoms with exposed electrons that are easily captured by the atoms that make up the comb. The comb then was charged negatively. Most materials when exposed to the atmosphere will eventually either gain or lose electrons and become electrically neutral, so the cereal may be said to be neutral. It is known that a charged object will attract an uncharged or neutral object. The comb is charged negatively; the cereal is neutral. The comb attracts the cereal.

While the cereal is in contact with the comb, the extra electrons flow from the comb to the cereal. As the cereal gains the extra electrons, it becomes more and more negatively charged. Since like charges repel each other, the comb repels the cereal and it jumps off

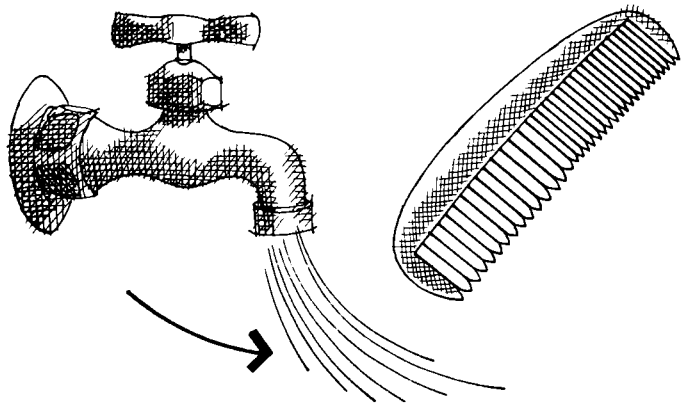
the comb. When the cereal is touched with the tip of a finger, the electrons from the cereal travel to the finger. The cereal becomes either neutral or positively charged once more, depending on the number of electrons that leave the cereal. It is again attracted to the comb.

PART B. This part works on the same principles as Part A. Charge a comb and bring one end to a small amount of fine, dry sawdust. Now hold the comb in a strong light so that you can observe what happens. Specks of sawdust will start darting out into space.



Explanation: The negatively charged comb attracted the neutral sawdust. As soon as the sawdust came in contact with the comb, the electrons from the comb traveled to the sawdust. The sawdust became negatively charged. Then both the comb and the sawdust were negatively charged. The sawdust jumped off the comb because like charges repel each other.

PART C. Comb your hair and bring one end of the comb near a *fine* stream of running water from a faucet. Keep moving the comb away from the water. You will no-



tice that the water follows the comb for a short distance. This works because the charged comb attracts the water that is neutral.

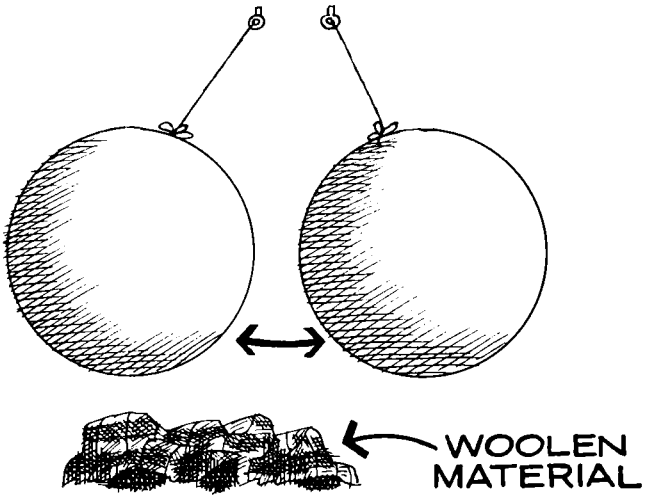
PART D. Balance a pencil on an egg and ask a friend to spin the pencil without either touching or blowing on it. It can easily be done if one knows how. Just bring a negatively charged comb near the point of the pencil. The pencil will follow the comb. The egg may also spin with the pencil if the resistance is not too great.

The pencil follows the charged comb because a charged body will attract an uncharged body. The pencil is neutral.

EXPERIMENT 47 MAKING BALLOONS HOP ABOUT

In the previous experiment we stated that when a comb is rubbed with woolen material or passed through hair, it gains electrons. It becomes negatively charged. Let us use this knowledge to determine static charges on other items, such as two balloons.

Materials: Two balloons, a piece of woolen material,



fine thread, a comb, a glass rod or a thermometer stem, and a piece of silk.

Procedures:

1. On a *dry day* inflate the two balloons and suspend them so they are free to swing about and yet touch each other. They should be about two inches apart. Rub the balloons with woolen material and then let them go. Do not touch them too long. The balloons will tend to swing apart. This means that the charges are alike on both.

8. Pass a comb through a crop of thick, dry hair. Bring one end near one of the balloons; then bring the comb near the other balloon. In both cases, the balloons will hop away from the charged comb. This shows that the balloons are also negatively charged.

3. Bring a finger near one of the balloons. It will stick to your finger, which is neutral, and therefore can absorb the excess electrons from the balloon. Now allow this balloon, while it's touching you, to come in contact with the other balloon. They will attract each other. When you touched the balloon, the electrons from it

traveled into your body. This caused it to become neutral. Since the other balloon was still negatively charged, the balloons attracted each other.

4. Now rub a glass rod (an old glass thermometer stem will do) with a piece of silk or nylon. Hold one end to a negatively charged balloon. The balloon will be attracted to the rod. This indicates that when glass is rubbed with silk, the silk takes the electrons from the rod. The rod now has an excess of protons (a lack of electrons). It is positively charged. The balloon is attracted to the rod because unlike charges attract each other.

Why some materials give up electrons

No doubt, while performing these experiments on static electricity, you have wondered why some materials give off electrons while others take them on. Physicists have an explanation.

When you rub hard rubber (or almost any plastic) with wool or fur, the rubber picks up the electrons from these materials. The molecules of such materials have atoms in which millions of electrons are darting about *freely*. Since the electrons are more firmly bound to the hard rubber rod than to the wool, during rubbing, the electrons migrate from the wool or fur to the rubber or plastic rod.

When you rub a dry glass rod with silk, the silk removes electrons from the glass, thus leaving a positive charge on the glass and making the silk negative. In this case, the compounds that make up the glass have atoms

with more freely moving electrons than those of the silk. As a result the electrons move from the glass rod to the silk.

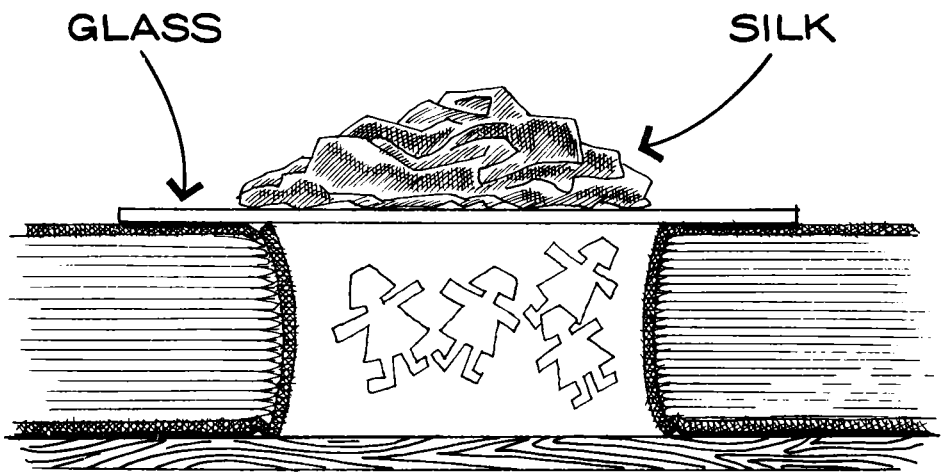
Experiment 48 Our dancing dolls

Here is another experiment which has an amusing effect. It can be explained in terms of what was learned in the previous experiments about static electricity.

Materials: Two thin books, a piece of glass plate about 8″ x 10″ (a window pane will do), tissue paper, and a piece of silk or nylon.

Procedures:

1. Lay the books on the table about four inches apart, and place the piece of glass over them.
2. Cut tiny pieces of tissue paper (about ⅛-inch square) and place them on the table between the books and under the glass. If you cut the paper in the form of dolls, the experiment becomes more interesting.
3. Rub the glass vigorously with a silk or nylon cloth.



Explanation: When the glass is rubbed with silk (or nylon), the silk receives electrons from the glass. The silk is negatively charged. The glass, as a result, has an excess of protons and is positively charged. The paper dolls are neutral and are, therefore, attracted to the charged glass plate. When in contact with the glass, the dolls surrender some of their electrons. This causes them to have a positive charge and they are therefore repelled. When on the table, they pick up electrons from the air and become neutral. Again they jump up to the glass plate to share their electrons with the protons. This process can be repeated as long as the glass has an excess of electrons.

Experiment 49 Making an electroscope

So far, in this chapter, we have learned that a comb will have a negative charge when passed through hair or when rubbed with wool; that a glass rod will have a positive charge when rubbed with silk; that a charged body will attract a neutral body; and that like charges repel and unlike charges attract. We have learned about these properties using somewhat crude equipment. We can obtain better results with the use of an electroscope. A microscope helps you see things that are small; an electroscope is an instrument that helps you to study small amounts of electric charges.

Materials: A wide-mouth bottle (a cider jug will do, although it's a little easier to make an electroscope if

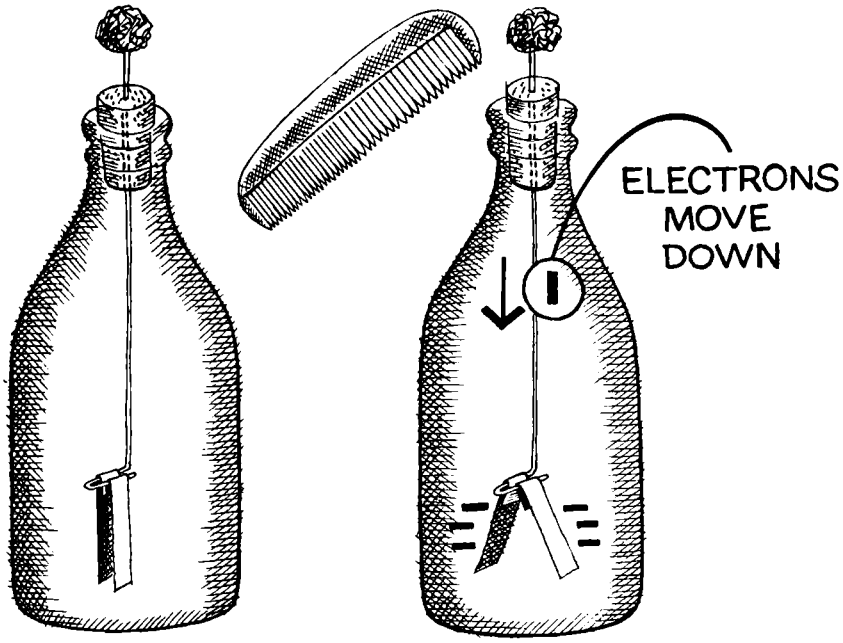
the bottle-mouth is more than one inch wide), a dry cork to fit the bottle, wax, aluminum foil, an 8-inch piece of heavy copper wire, a comb, a balloon, wool, silk, a candle, a glass container from a toothbrush, pieces of cloth made of rayon, nylon, etc.

Procedures:

1. Remove the insulation from the wire, and force the wire through the cork. Leave about one inch of wire above the cork. Bend about 1½ inches of the lower end of the wire at a right angle. Now bend this part of the wire back on itself as shown.
2. Wax the cork to prevent the charges from leaking into the atmosphere. Wax is a good insulator. Be sure to seal the hole at the points where the wire enters and leaves the cork.
3. Cut two pieces of aluminum foil, each about 1½ inches long and not more than ¼ inch wide. Bend one end on each strip and place over the wire.
4. Heat the bottle over a radiator to remove all moisture and some of the air.
5. While the bottle is warm, carefully insert the cork with its attachments in the neck of the bottle. The strips should be at least one inch from the bottom of the bottle.
6. Make a ball of aluminum foil about the size of a marble and fasten it on top of the wire that projects through the cork. Now you have made an electroscope.

USING THE ELECTROSCOPE:

1. Using your hair or some woolen material, charge the



comb and bring one end near the ball. Do not touch the ball. The ends of the foil inside the bottle will move apart. The electrons from the comb travel down the wire to the aluminum strips. Both strips are negatively charged, so they repel each other.

2. Remove the comb. The strips will gradually fall together again as the excess electrons move back up the wire and leak off into the air. Eventually, the strips will become uncharged again.

3. Rub a glass rod or a test tube briskly with silk cloth. Bring the charged rod near the ball. The aluminum strips will part as before. The protons on the glass rod attract electrons upward along the wire to the ball. This causes the strips to become positively charged. But again, since both strips have the *same* charge, they repel each other.

4. Remove the charged glass rod. The electrons that have been attracted to the ball now return to the strips. The strips will fall together as they become neutral.

You are now ready to test the static charges on many materials. You can do this by first charging the electroscope negatively with a comb. If the material causes the strips to collapse, you know that the charge on this material is positive. If the strips are spread farther apart, you know that the object has a negative charge.

You can have fun trying various experiments with your electroscope. In your notebook you might list all combinations that cause a positive charge and all those that cause a negative charge.

7

CURRENT ELECTRICITY

Go THROUGH your home and count the number of places where electricity is used. Do the same on your way to school or when you go shopping with your parents. As you look about you, you will realize how dependent we are on electricity for the many activities of our life. The electricity in our homes, schools, and stores is not the same as that about which we studied in the previous chapter.

A spark of static electricity will not toast your bread or heat an electric iron. It will not start your car or run your electric train. True, static electricity can pick up pieces of paper, but it cannot pick up tons of scrap iron. It will not even light your flashlight. For our many electrical appliances or toys we need current electricity. Current electricity consists of a stream of the negative particles called electrons. This stream is measured in volts and amperes. If you think of the stream of electrons as a stream of water, the volts represent the amount of pressure behind the water, and the amperes the quantity of flow.

Let us now turn our attention to some of many fascinating experiments dealing with current electricity.

Experiment 50 Making a complete circuit

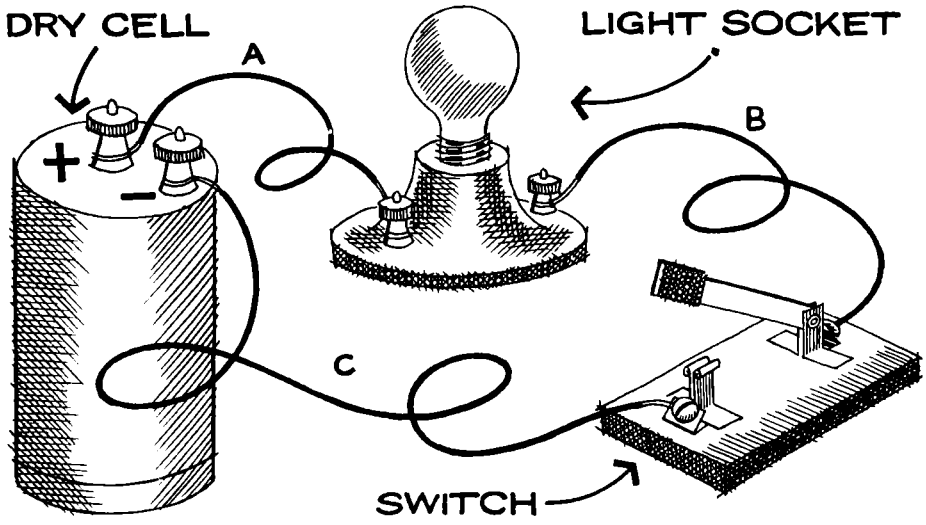
Current electricity will not flow from a dry cell unless a complete path is made for its travel. We call such a path a complete circuit.

Materials: A switch, a dry cell, insulated copper wire, a flashlight bulb (1½-volt), and a socket for the bulb. If you don't have a regular switch, you can make one from two narrow pieces (½" x 1") of metal from a tin can as shown in the diagram on page 162.

Procedures:

1. Cut the wire into three pieces — two 6-inch pieces and one 12-inch piece. Then remove about one half inch of insulation from each end of the three wires.
2. Connect one end of wire *A* to a terminal or binding post of the dry cell, and connect the other end of the wire to a terminal on the light socket.
3. Connect wire *B* to the other terminal of the light socket, and to one of the terminals of the switch.
4. Connect wire *C* to the other terminal of the switch and to the second terminal of the dry cell, as shown in the diagram.
5. Close the switch by pushing the small lever between the metal snaps. Follow the flow of electrons from one of the binding posts of the dry cell through the circuit and back to the other binding post of the dry cell.

Explanation: When the switch is down, or closed, current flows from the dry cell through the switch, then through the light bulb, and back to the cell. Should



the wire be disconnected at any one terminal or cut at any point, or the small level raised sufficiently, the bulb would not light. Under this condition we have a broken or incomplete circuit.

A switch in a circuit serves the same purpose as a drawbridge over a stream. It makes possible the flow of electrons from one side of the switch to the other side. Car traffic cannot cross a river when a drawbridge is open. Neither can electrons move when a knife switch is open.

There are various kinds of switches, but they all work on the principle of completing or breaking circuits. In place of a knife switch you may be using a push-button switch. This sort of switch is commonly used for doorbells, but it would work in this experiment too. When you press down on the small button, a wire spring inside it touches the wire or part of the binding post that is connected to the dry cell and the light socket. There is now a complete circuit and electrons

will flow throughout it. When you lift your finger from the push button, the spring rises and no longer touches the wire. The circuit is broken and electricity cannot flow to the bulb. The light goes out.

Experiment 51 Making a dry cell

For the experiments on static electricity, we obtained our electric energy from a charged comb. In these experiments we shall obtain our electric energy from dry cells.

Take a worn-out dry cell and cut it lengthwise with a hack saw. Down the center you will find a round carbon rod which is referred to as the positive binding post or terminal. There is another binding post attached to the outer zinc shell. It is called the negative binding post. Inside the cell and packed around the carbon rod is a mixture of chemicals. These chemicals, the carbon rod, and the zinc shell make it possible for the cell to give off electricity. The sealing wax at the top prevents the cell from drying out.

We can make a dry cell even though it will not give off enough electricity to light a bulb or ring a bell. It will, however, show that a combination of two different metals with an acid or salt solution between them will produce some electrons.

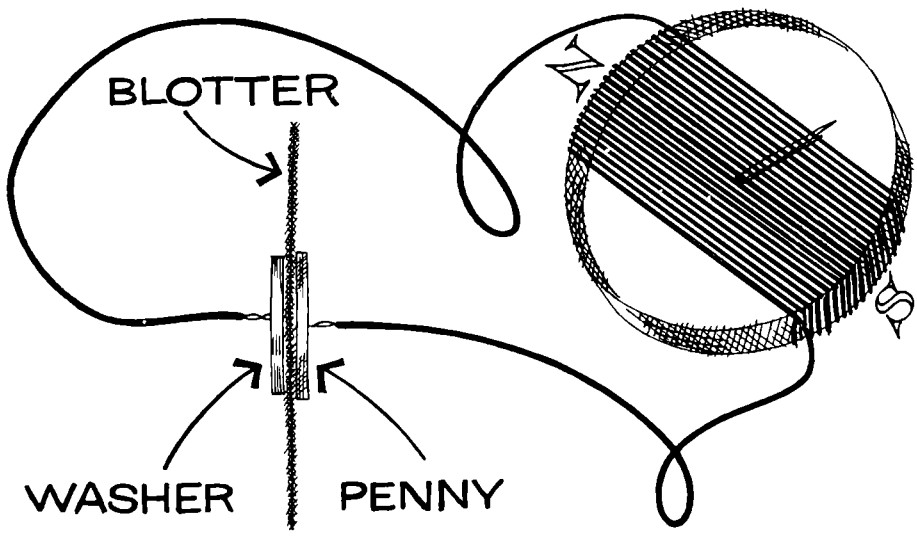
Materials: A penny, a blotter, a teaspoon of strong salt solution (add as much salt as a teaspoon of water can dissolve), 4 feet of fine insulated copper wire, a piece of

zinc or an iron washer, Scotch tape, and a magnetic compass.

Procedures:

1. Wrap about 50 turns of wire firmly around the compass, leaving about 6 inches of wire free at each end. Fasten the wire to the compass with tape.
2. Scrape the insulation from both ends of the wire for a distance of about one inch.
3. Moisten the blotter with the salt solution, and place the penny on one side and the piece of zinc or the washer on the other side.
4. Next, place one wire end on the penny and the other wire end on the other metal. Observe what happens to the compass needle when the wires touch the two different metals, and again when the contact is broken.

Explanation: In this dry cell the penny, iron washer, and the salt solution made it possible for electrons to flow. They served the same purpose as the zinc, carbon, and chemicals in the commercial cell.



The movement of the compass needle gave evidence that a current was flowing through the wire. A wire carrying an electric current can produce a magnetic field that is strong enough to affect a compass needle, as will be seen in the next chapter.

You may want to make another dry cell by putting a small piece of copper strip and one of zinc strip into a lemon. Repeat step 4 above.

Experiment 52 Conductors and nonconductors of current electricity

In previous experiments on static electricity, we learned that such materials as rubber, wax, paper, silk, plastic, glass, and wool will hold a static charge. This is not true with current electricity. Current electricity will not pass through any of the above materials, but it will travel through metals such as copper, iron, aluminum, silver, and many others. Materials that carry an electric current are called conductors, and those that do not are called insulators.

Make a table, similar to the one below, and determine which of various materials are conductors and which are insulators.

Material	Conductor	Insulator	Special Comment

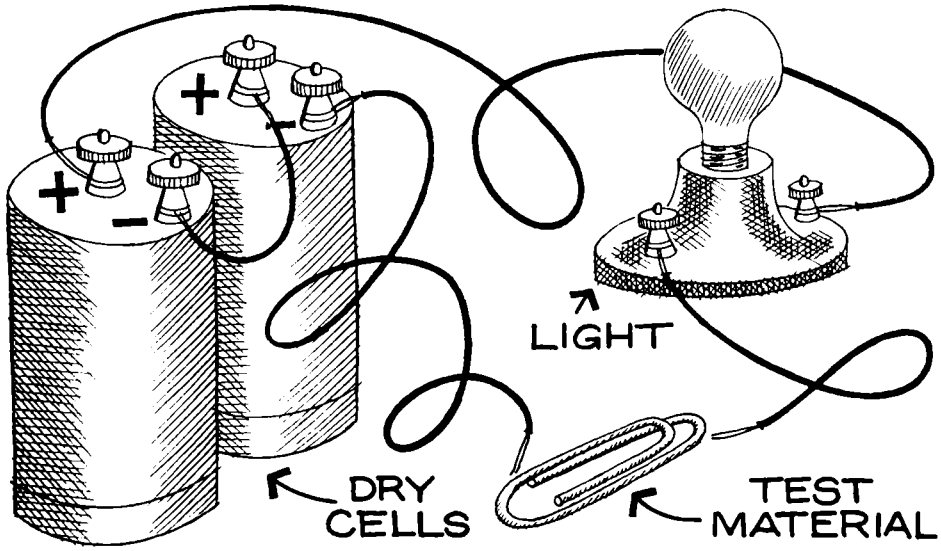
Materials: Two dry cells, light bulb and socket, wire, and various solid materials as mentioned above.

Procedures:

1. This experiment is set up in the same way as Experiment 50 except that we need two dry cells working together to produce an easily detectable flow of electrons. Observe that the positive binding post of one cell is connected to the negative binding post of the other.

2. Take the two loose ends of the two different wires (these were attached to the switch in Experiment 50) and bring them together. If the cells are working properly, the light will glow. (Be sure the insulation has been removed from each end for a distance of about one half inch.)

3. Touch the bare ends of the wires to two points on various objects. Record whether or not the light glows. You may even want to indicate the degree of brightness of the bulb for each sample. You may want to test



these objects: paper clip, eraser, chalk, hair, coins, lead in a pencil, desk top, glass, drop of distilled water, drop of salty water, etc.

Explanation: The metal objects made it possible for the bulb to glow, showing that the circuit had been completed. Metals are good conductors of electricity. Nonmetal objects prevented the bulb from glowing, showing that the circuit had not been completed. Nonmetals are insulators.

Distilled water should not cause the bulb to glow, but the salty water should. Certain chemical compounds when dissolved in water will make it possible for the electrons to flow through the solution. Such a solution is classified as a conductor of electricity.

We use insulators on all our electric appliances. The handles or buttons on irons, radios, heaters, sockets, extension cords, etc., are made of materials that are good insulators, or nonconductors, of electricity.

Experiment 53 Why only some wires heat up and give off light

So far in this chapter we have learned that electricity is made up of fast-moving electrons, that a complete circuit is necessary for the flow of electricity, and that all materials do not allow electrons to travel through them. Next, let us see how electricity can make heat without a flame and how electrons can make a conductor glow sufficiently to give off light.

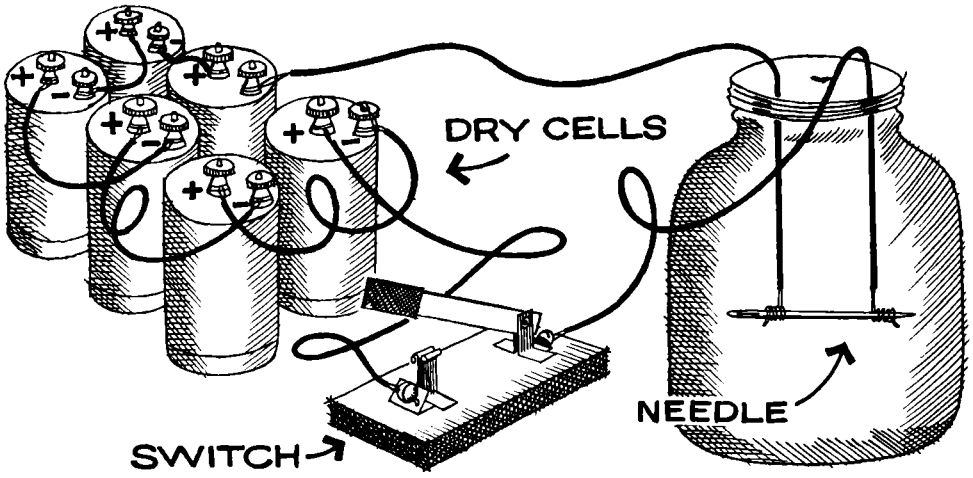
The thick copper cables strung along the steel towers of high-tension lines carry many more electrons than a wire in a toaster or a light bulb. Yet the cables do not heat up nor do they give off light as does the toaster wire. Why is this so? Let's find out by experimenting.

Materials: Six dry cells or an electric-train transformer, insulated copper wire, a small steel needle, a switch, a wide-mouth bottle, and a lid or stopper to fit the bottle.

Procedures:

1. Connect the dry cells in series. This is done by connecting the center post of one cell to the outer post of another. The center posts are often marked with a plus sign (+), the outer posts with a minus sign (−). When cells are connected in series (+ to −), we get the *sum* of the *voltage of the cells.*
2. Insert a switch between one of the wires from the dry cells and the bottle, as shown in the diagram. Attach a wire to the other terminal on the switch.
3. Place the two free ends of the wires through the stopper or lid.
4. Wind the ends of the wire around the two ends of the needle. Place the needle in the bottle.
5. Complete the circuit by pushing down on the switch. Open the switch as soon as the needle begins to glow. You can repeat this part several times before the filament (in this case, the needle) burns out.

Explanation: All wires offer some resistance to the flow of electricity through them. Some, however, offer



more than others. Copper wire is a better conductor of electricity than the steel needle or the tungsten in light bulbs. The steel needle offers high enough resistance to cause it to heat up to a point where it begins to glow.

Copper cables carrying a high voltage will not heat or glow because they are thick. It is a known fact that the thicker the conductor, the less resistance it offers to the flow of electrons. The thinner or the finer the conductor, the higher is its resistance. This is the reason why the light bulb has very fine tungsten wire. We can understand this better by thinking of an illustration. Let us say you crawl through a pipe that's about two feet in diameter. You would encounter very little trouble — the pipe would offer very little resistance. Now you try to crawl through a pipe one foot in diameter. This smaller pipe would offer much greater resistance. If you insisted on getting through the pipe, no doubt you would get pretty hot too because of the increase in temperature resulting from friction.

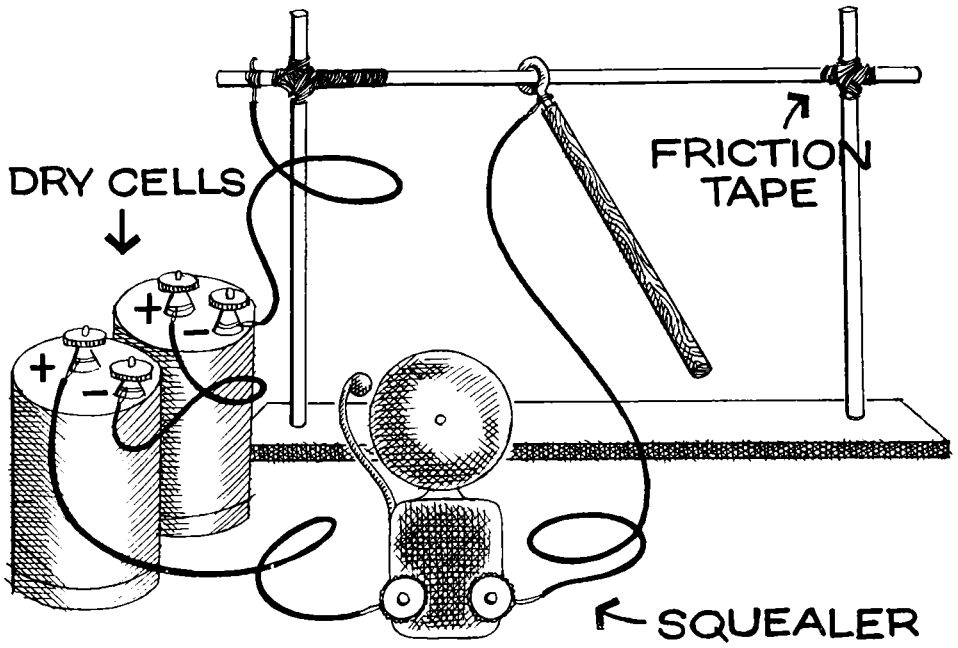
Experiment 54 Making a "nervousness" tester

How steady is your hand? Do you become more nervous when you are asked certain questions? This experiment will help you find out.

Materials: Two dry cells, an iron rod, a small iron ring that fits closely over but does not touch the rod (if you can't find a ring of the right size, you can make one out of wire), two stands, a bell, Scotch tape, and about 4 feet of insulated bell wire.

Procedures:

1. Fasten the metal ring to a wooden handle. Slip the ring over the iron rod. Run a wire from the ring to the bell.
2. Connect the dry cells in series. Run a wire from one of the terminals of the dry cell to the second terminal of the bell.
3. Support the rod, with the ring on it, on two stands. Insulate the rod with friction tape where it touches the supports.
4. Connect a wire to the second terminal on the other dry cell and to one of the ends of the rod. Be sure the wire is in contact with the metal rod.
5. Ask a friend to move the ring across the rod without allowing the ring to touch the rod. Measure the distance that he was able to move the ring before the bell rang.
6. Question your friend about some event while he is moving the ring over the rod.



Explanation: The distance the ring is moved over the rod without the bell ringing depends on the space between the ring and the rod, and the nervousness of your friend. The bell will "squeal" on your friend every time the ring touches the rod. When the ring touches the rod, a complete circuit is formed.

Experiment 55 The art of electroplating

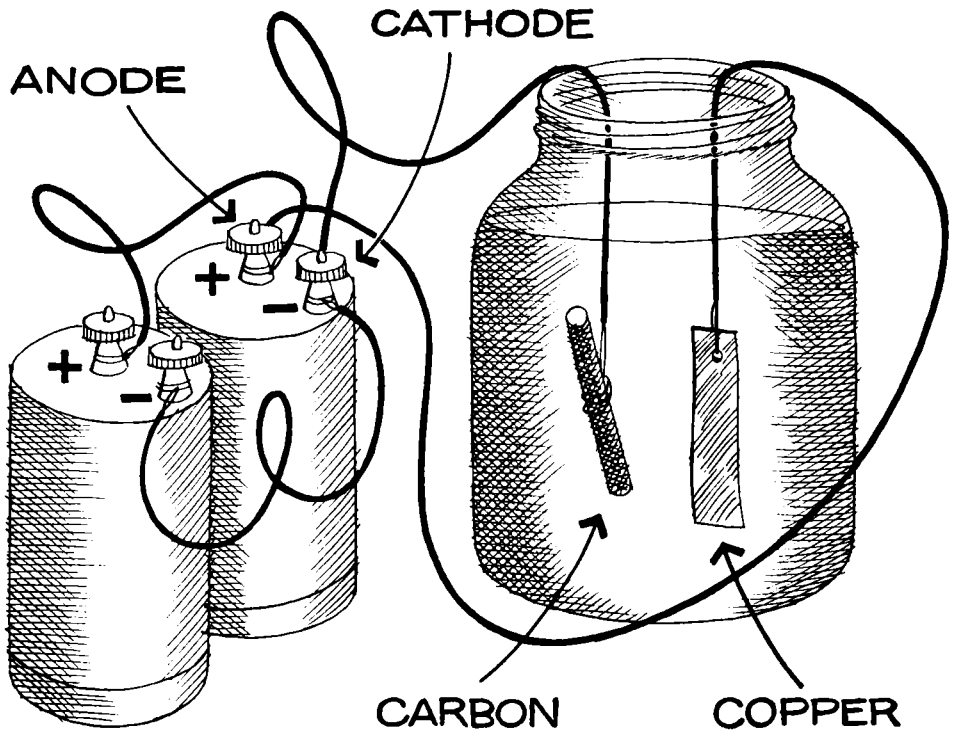
Pure water will not conduct electricity very well. If it is 100 per cent pure, its conductivity is very small indeed. If, however, we dissolve certain chemicals in water, the resulting solution may conduct an electric current. Chemicals that can be dissolved in water for this purpose are table salt, vinegar, lye, copper sulfate, and thousands of others. A solution that conducts an electric current is called an electrolyte. Manufacturers use this knowledge to plate various materials — silver-

ware, bumpers on cars, jewelry, and the like. We can show how electroplating is done by performing this experiment.

Materials: Two dry cells, copper wire, a glass jar, a carbon rod from the center of an old dry cell, and copper sulfate (you can buy an ounce at a drugstore).

Procedures:

1. Dissolve a teaspoon of copper sulfate in a glass of water.
2. Connect the wires to the dry cells, using parallel circuits. This is done by connecting the center binding posts of the two dry cells with one piece of wire, and the outer posts of the two dry cells with another. Should you desire to hasten the process, then connect the cells in series. Better plating is obtained when the voltage is low but continuous.
3. Attach the carbon rod to the wire that is connected to the negative terminal, or cathode. This is the outer post.
4. Attach some coiled copper wire or a small sheet of copper to the positive terminal, or anode. This copper must have no insulation.
5. Place both the copper metal and the carbon rod in the copper sulfate solution for about one minute. Observe what happens to the rod.
6. Take the rod and the copper out of the solution. Place the rod on the anode wire and the copper on the cathode wire. Put both back in the solution. Examine after a few minutes.



Explanation: The electrons from the dry cells made it possible for the copper atoms from the metal to travel to the carbon rod. There they were deposited as pure copper. When the poles or materials were reversed, the copper atoms left the carbon rod and went back to the copper sheet or the coil of copper wire. This process is known as copper plating, or electroplating. Various materials can be plated with gold, silver, nickel, or chromium.

In industry this process is used to purify copper. The impure slabs of copper are placed in large tanks. When the current is turned on, the electrically charged copper atoms from the slabs travel to the anode where they are deposited on special bars. The copper metal on these bars is almost 100 per cent pure.

Experiment 56 Fuses — our faithful guards

In all of our houses there are "electric watchmen" who protect our belongings from serious damage. We call them fuses.

The common fuse contains a special alloy through which electricity must flow to form a complete circuit. When we try to draw a dangerous amount of electricity from wires, the alloy in the fuse heats up and melts. This results in an incomplete circuit. To be of value, the alloy strip in a fuse must melt before damage is done to the electric appliances or to the wires in the walls.

In some homes, instead of the alloy melting in a fuse, the fuse "pops" out when an electric circuit is overloaded. In fuses of this type, the metal holding the fuse expands upon heating. This enables the fuse to spring out. The device is called a circuit breaker.

Fuses should not be replaced, regardless of the kind, until the trouble is found and corrected.

Materials: At least two dry cells, copper wire, rubber bands, a small lamp and socket, a large cork, thin aluminum foil from a gum wrapper, and a screwdriver.

Procedures:

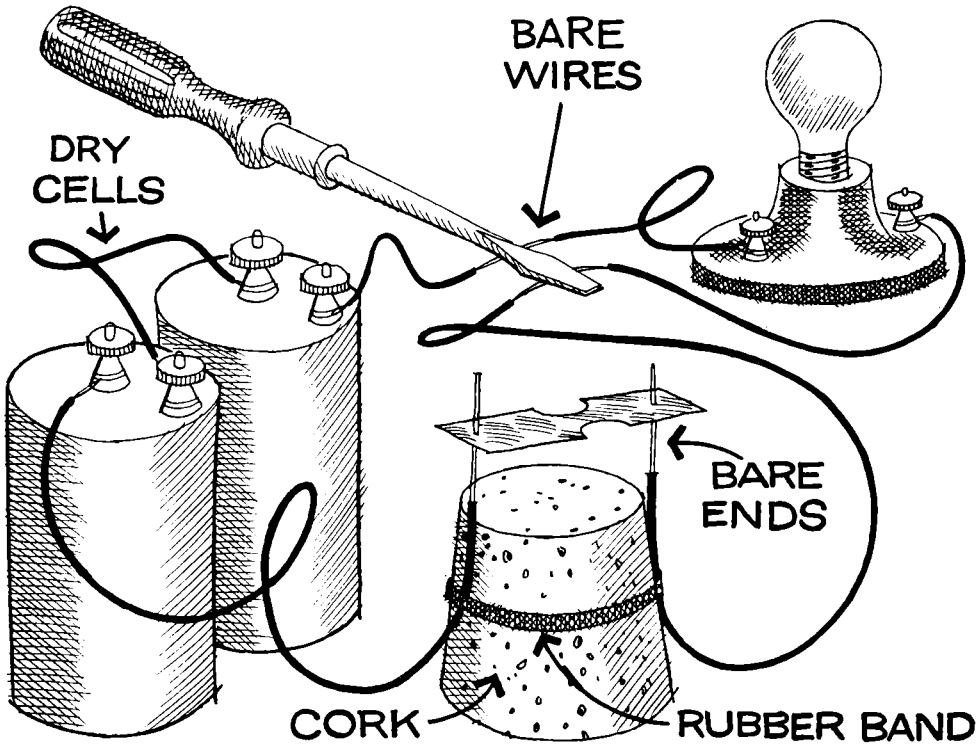
1. Connect the dry cells and the light in series as shown in the diagram.
2. Remove about an inch of insulation from each wire that is attached to the cork. Use rubber bands to fasten the wires to the cork.
3. Cut a piece of thin aluminum foil long enough to

reach from one wire to the other over the cork. The foil should not be more than ⅛ inch wide.

4. Remove about an inch of insulation from each wire near the light.

5. At this point, place the metal part of the screwdriver across the bare wires. This permits the current to by-pass the light bulb, and thus causes a short circuit. When this is done, observe what happens to the foil and to the glowing light bulb. If the foil fails to melt, it may be necessary to cut down on the width and thickness of the foil and to increase the number of cells in the circuit.

Explanation: If you think of the wire as a water pipe, the flow of electrons from the negative terminal of the



battery would be like a strong current of water, and the light bulb would be like a partly closed valve that would reduce the water flow to a trickle.

When the screwdriver is placed over the two bare wires, it permits the electrons to flow through much more easily. It is like allowing the flow of water to by-pass the valve. The full flow of the water would hit the weak spot (the fuse) and break it open. In like manner, when the current of electrons tries to pass through the fuse, where the passageway is restricted, the piece of aluminum foil becomes hotter and hotter until it melts. Once it has melted, of course, the circuit is broken and the flow of electrons stops. This is why a fuse is an essential safety device in any circuit that carries a heavy current.

We can put the light or appliances back into operation by removing the cause that produced the short circuit and by replacing the fuse with another of the same amperage.

8

MAGNETISM

We do not know who actually first discovered magnetism. We do know, however, that ancient Greeks used principles of magnetism. At least two thousand years ago they knew that a certain type of iron ore clung to the iron tips of their staffs. They also learned that this magic stone could give its power to a piece of iron. It is believed that in the early part of the twelfth century, a number of sailors of northern Europe used this special iron ore to magnetize long pieces of iron. They observed that such a piece of iron always pointed in the same direction when allowed to swing freely. Later they gave this ore the name "lodestone," or Leading Stone. The magnetic ore was used as a compass and it helped them find directions during their voyages over both land and sea.

Magnets play an important role in many devices used in homes and industries. They are used in electric motors, television sets, space missiles, telephones, atomic reactors, and in many of our electric toys. In fact, we can say that the magnet is the father of most of our modern electric appliances. If we want to understand the many jobs that magnets do for us, it is necessary to know a few things about the properties of magnetism.

Properties of magnets

Not all materials have magnetic properties, nor can all of them be magnetized. Iron, steel, cobalt, and nickel are the metals that can be magnetized the best. There are certain alloys — mixtures of specific metals — that can also be magnetized. Recently, scientists learned that liquid oxygen has slight magnetic properties.

Physicists are still puzzled by the mysteries that surround magnetism. We still don't know much about magnets and their properties, but are making use of what we do know. Physicists, however, do believe that when a piece of iron is magnetized, the atoms within it become little magnets. These atoms arrange themselves with their north poles pointing in one direction, and their south poles pointing in the opposite direction. We can show this by using a small sample of iron filings, a plastic case from a toothbrush, a magnet, and a lot of imagination.

You can either buy iron filings or make your own. To make them, obtain a piece of soft iron (not steel) from your parents or a junk dealer. Clamp the chunk of iron firmly in a vise and file it with a medium-coarse file. The finer the filings, the better they behave in the presence of magnets. Fill the plastic tube about a quarter full with iron filings and stopper it with either a cork or Scotch tape. Holding the tube in a horizontal position, pass the magnet over it several times in the same direction. You will notice that the filings tend to line themselves up.

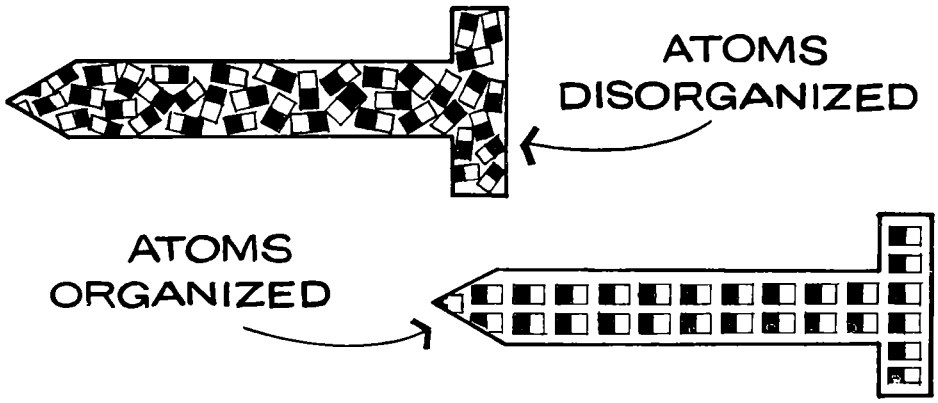
Now here is where your imagination comes in. If you imagine each iron filing as a single atom and all the filings together as a solid piece of iron, you will have an idea of what happens in iron when it is magnetized. You can show that the filings have been magnetized by the use of a compass.

The earth itself is one huge magnet with a north pole and a south pole, but every magnet, no matter how small, has, in general, two ends or poles. If it is free to move, it will line up with the earth's poles, and the end that points north is said to have north (N) magnetism. We refer to the north-pointing end as the north pole of the magnet, the south-pointing end as the south pole. Every iron filing in our plastic tube has an N pole and an S pole. When the north pole of a magnet is brought near the north pole of a second magnet, the two poles repel each other. If two south poles are brought near together, they too will repel each other. If, however, a north pole and a south pole are brought close together, the unlike poles attract each other. No one knows why this should be so, but at least we know from experience that it always works. It is one of the basic laws of physics that may be stated thus: *Like magnetic poles repel each other; unlike poles attract each other.*

But there is more to magnets than simple attraction and repulsion, as later experiments in this chapter will show. Iron filings arrange themselves in curved patterns when sprinkled over a piece of paper under which there is a magnet. This area, or field, is described as

being composed of magnetic lines that are called magnetic lines of force. The magnetic lines of force attract iron filings and thus we can make an outline of the curved lines on the paper with the iron filings. Magnetic lines of force, as one can see from the earth's lines of force, can penetrate air, water, glass, paper, cloth, and many other substances. They can even penetrate a vacuum.

You may have had a magnetic toy which, after a period of time, lost its magnetism. You may have wondered: Why did it lose its magnetism? Can it be remagnetized? Magnets can lose their magnetism by improper storage, or by heating, hammering, or jarring them. When a magnet is heated or hammered, the arrangement of the atoms is disorganized.



The answer to the second question is: Iron, steel, cobalt, nickel, and certain alloys can be remagnetized in the same way they were originally magnetized. So your toy could be remagnetized by passing a strong magnet over it several times. Another way would be to pass a

direct current (electricity from batteries) around the magnetized toy. This method is more effective than using a magnet. We shall magnetize materials when we make electromagnets in several of the experiments.

Experiment 57 Making magnets

We know that certain materials can be made magnetic that were not so before. In this experiment we shall magnetize iron by three different methods.

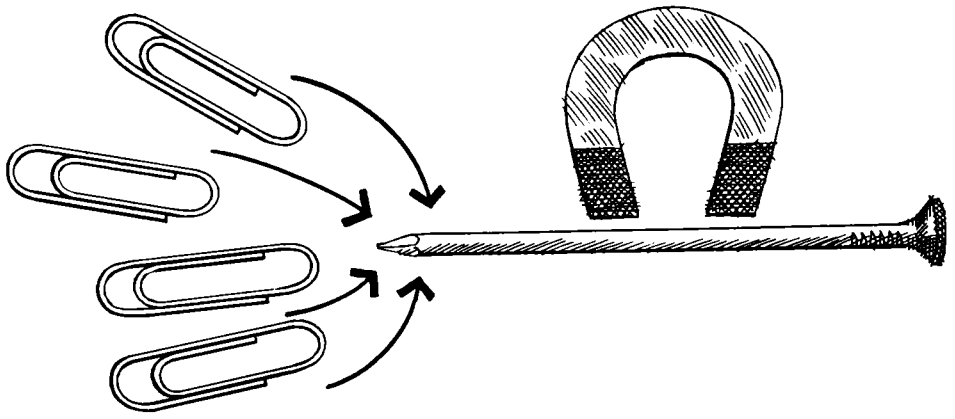
Materials: Three large nails, a steel needle, 3 feet of insulated copper wire, a strong magnet, a long iron or steel rod (such as a solid curtain rod), and some iron filings or steel paper clips.

Procedures:

Method A

Place an iron nail in contact with the end of a permanent magnet. Bring the nail, still in contact with the magnet, to the box of paper clips or iron filings. Remove the magnet from the nail.

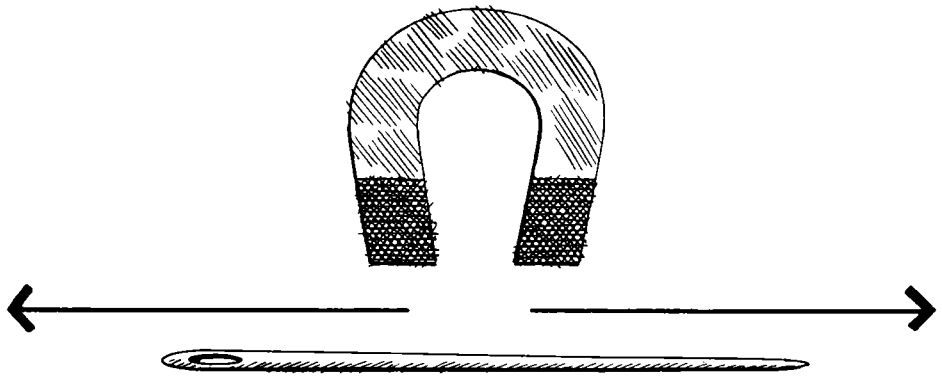
The nail, when in contact with the magnet, also be-



comes a magnet. The paper clips will adhere to the nail as long as the nail is in contact with the magnet. When the magnet is removed, the nail loses its magnetism. The paper clips fall off.

Method B

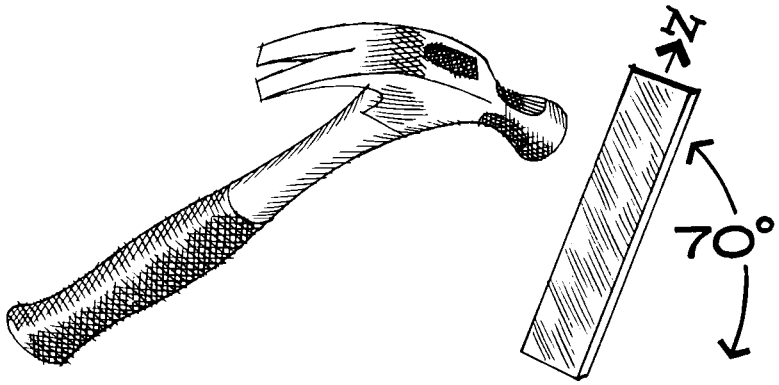
Take the steel needle and rub the magnet over it. Start at the middle of the needle and pass one end of the magnet toward one end of the needle. Do likewise on the other end of the needle, using the other end of the magnet. Pass the magnet over the needle in one direction only. Try picking up some of the paper clips with the needle. Use both ends of the needle.



By passing the magnet over the needle, the atoms in the needle were lined up so that all their north poles pointed in one direction and their south poles in the other. You will see that both ends of the needle attract small iron or steel objects.

Method C

Take the long iron or steel rod and tilt it at an angle of about 70° up from the floor, and point the rod high and toward the north. (What you are doing is lining



the rod up with the axis of the earth itself.) Now hit the upper part of the rod several times with a hammer. Test the rod with a compass. Try to pick up some small iron objects or iron filings. It may be necessary to try this experiment several times before you get satisfactory results.

The rod is made into a magnet because the hitting of the rod causes the atoms to line up with the magnetic lines of force of the earth.

Atoms in iron radiators and in flagpoles are lined up with the earth's magnetism after long periods of exposure. You can prove this for yourself. Hold a compass near the top of a radiator. Observe carefully the compass needle as you move the compass to the foot of the radiator. At the bottom of the radiator, the compass needle will point in the direction opposite from the one to which it pointed at the top of the radiator. One end of the radiator is a north pole, the other a south pole.

There is still another way of making a magnet — by use of electricity. We will learn about this method in a later experiment.

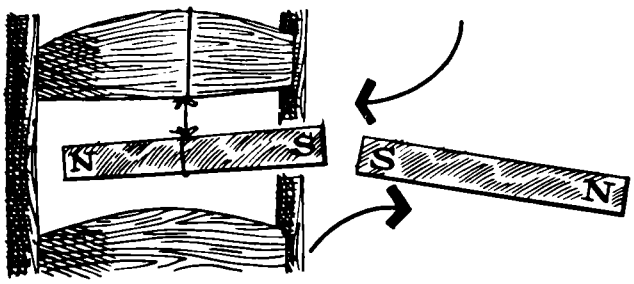
Experiment 58 Laws of magnetism

In the previous experiment we learned ways to make a magnet. In the next two experiments we shall study some of the properties of magnetism. The first one will illustrate the law of magnetism.

Materials: Two bar magnets that you may be able to obtain from a dime store or a scientific supply house, one foot of fine thread, and some iron filings.

Procedures:

1. With chalk label the ends of each magnet N and S. The S pole will attract the N part of a compass needle.
2. Suspend one of the bar magnets from a support by use of the string so that it will swing freely. Note that it will come to rest with the N pole pointing toward the earth's magnetic north pole.
3. Bring the north end of the other magnet to the north end of the suspended magnet. Then try bringing the two south ends near each other.
4. Bring the north end of the other magnet to the south end of the suspended magnet. Now bring the south end of the other magnet to the north end of the suspended magnet.



Explanation: This experiment illustrates the law of magnetism which we noted earlier, that like magnetic poles repel each other, and unlike poles attract each other.

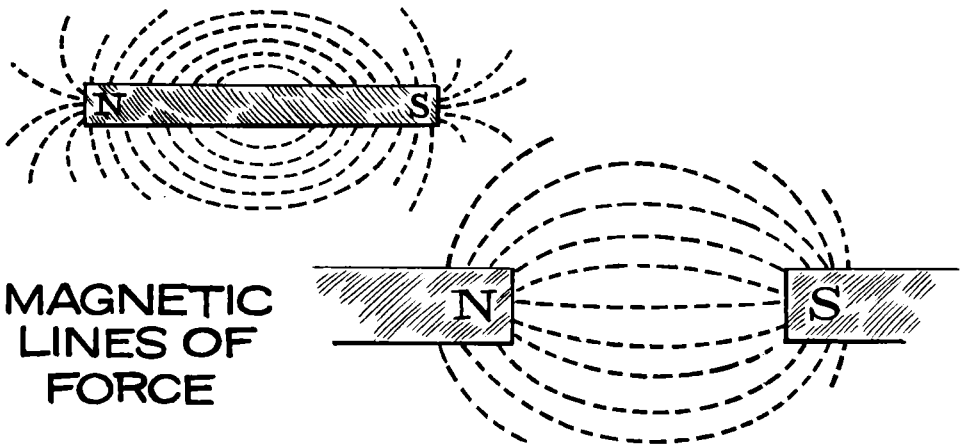
Experiment 59 Magnetic lines of force

The English scientist Michael Faraday was one of the first to study the space around a magnet. He observed that iron filings, when sprinkled over a sheet of paper under which was a magnet, arrayed themselves in a specific pattern of curved lines. The lines formed by the filings are called *magnetic lines of force.* The total space covered by these lines is referred to as the *magnetic field* of the magnet. Let us repeat his experiment.
Materials: Two magnets, iron filings, and a 4″ x 6″ paper card. Waxed paper may be used in place of the card.
Procedures:
1. Place a bar magnet on the table with the card over it.
2. Sprinkle iron filings very lightly over the card. Use a salt shaker. You may obtain iron filings at a machine shop or a hardware store where they thread pipe. Greasy filings must be washed with alcohol or a strong detergent before being used. Place the iron filings in a clean can — a can from concentrated fruit juice will do. Add to the can about a tablespoon of household detergent, and then fill the can with hot water from the faucet. Stir the contents with a ruler or an old table-

spoon. Drain off the oily water and rinse with additional hot water. Repeat the entire washing process until the rinse water does not appear oily. Spread the filings on newspaper and allow them to dry. They will then be ready for use.

3. Tap the card gently. You will see that the filings arrange themselves in lines reaching out from the poles of the magnet.

4. For a permanent record of this experiment, place the bar magnets on the table with unlike poles facing each other as shown in the diagram. Place a sheet of waxed paper over the magnets. Sprinkle filings over the paper. Tap gently. Raise the paper without disturbing the filings and put it over a hot radiator. After several minutes, remove the waxed paper with the filings and allow it to cool. Tap off the loose filings. You will observe that the filings, upon heating, melted lines into the wax. You can preserve the waxed paper as a record of the experiment for your notebook. The lines of force traveled from one pole to the other.



MAGNETIC LINES OF FORCE

Another useful method is to spray the pattern with a transparent plastic coating such as Krylon. The resulting pattern often shows that the magnetic field is three-dimensional, while the pattern of filings on waxed paper shows only a two-dimensional cross section of the field.

5. Repeat the above part, but this time place like poles facing each other. You will see that the lines formed repel each other as shown in the diagram.

Experiment 60 A compass in a minute

Ancient sailors used compasses similar to the one we shall make to tell directions. These men did not venture very far away from the shore, nor did they do much sailing at night. They were afraid of getting lost. The discovery and understanding of the compass changed all that. We can duplicate the earliest form of a compass in a minute. It will, nevertheless, work as well as the best of them.

Materials: A magnet, a cork, a needle, a shallow dish, water, thread, a 4″ x 6″ card, and a glass bottle with a wide mouth.

Procedures:

1. Magnetize a needle as described in Experiment 57, Method B. Be sure to stroke always in the same direction and to move the magnet away from the middle of the needle.

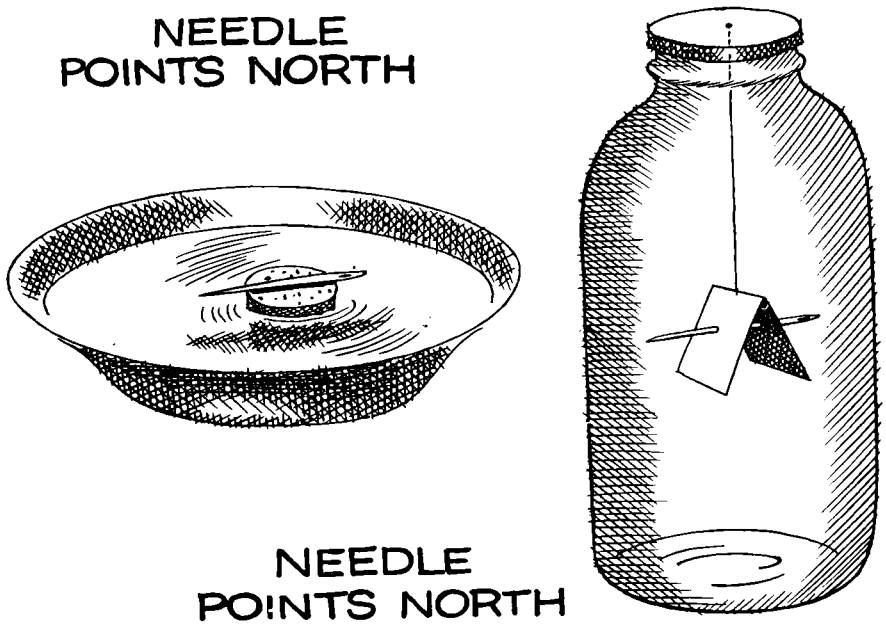
2. With a sharp knife or razor blade, cut a thin slice of

cork and float it on the water in the dish. Balance the magnetized needle on the cork. A piece of gum or sticky waterproof tape may be used to keep the needle in place. Place the dish and the compass out of strong air currents and away from magnetic substances.

3. Another kind of compass can be made by putting a magnetized needle through a folded card as shown. The card *must* be suspended by a very light thread. If it is suspended in a bottle, it will not be affected by air currents in the room.

Explanation: If you have done a good job, the needle will swing around until it assumes the north-south position. It behaves this way because of the earth's magnetic field.

You may want to satisfy yourself that this compass is reliable. This you can do by comparing its reading with that of a purchased compass.



THE RIGHT WAY TO USE A COMPASS

Hold the compass so that the needle swings freely. Make sure that there is no iron object or another magnet in the immediate vicinity. One end of the needle will always point in a northerly direction. This end is called the north-seeking pole. Next, turn the compass case, or the direction of the card under your bottle, so that the N printed on the face is under the correct point of the needle. Now you can read the other directions on the compass card. When facing the same direction as the north-seeking pole is pointing, the east will always be on your right and the west on your left.

9

ELECTROMAGNETISM

ALTHOUGH scientists do not yet understand the reason it should be so, it is known that electricity and magnetism are closely related to each other. For example, electric current running through a wire sets up a magnetic field. This can easily be detected by using an ordinary compass as shown in Experiment 51. If you coil the wire around an iron rod, the rod acts as a magnet when electricity flows through the wire. This device is called an electromagnet.

Because they can be made far more powerful than ordinary magnets, and because they can be turned on and off at will, electromagnets have thousands of uses in our society. The telephone, the telegraph, and electric motors all depend on electromagnets. In this section we shall make actual working models of some of these devices.

EXPERIMENT 61 AN ELECTROMAGNET

A type of magnet that makes motors possible, that can lift great weights, and that makes it possible to send messages by either telegraph or telephone is called an electromagnet. An electromagnet differs from the other

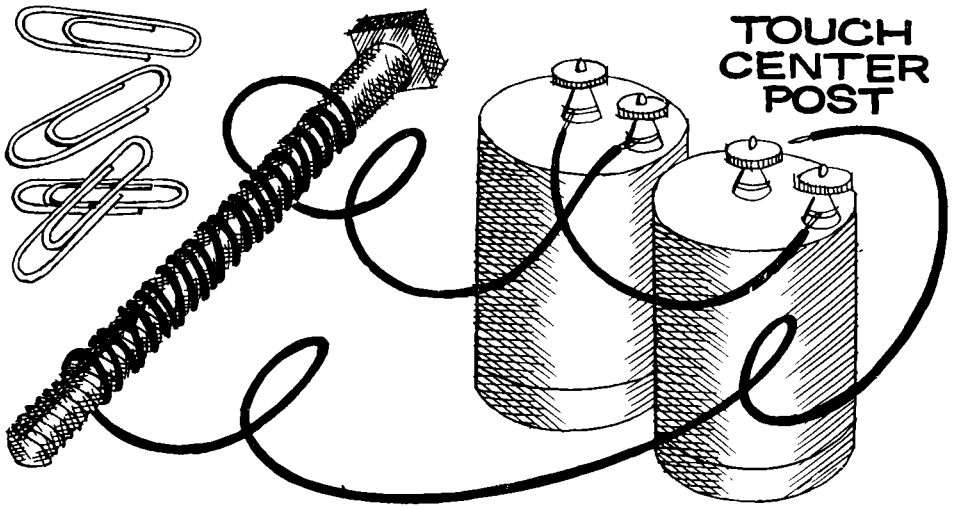
magnets we made in that it depends upon electricity. To perform the experiments in this section you will need an electromagnet. A simple one is not hard to make.

Materials: A 4-inch iron bolt or rod, three feet of bell wire (obtainable in a hardware store), several paper clips, and two dry cells. Dry cells can be purchased at any hardware store, and unless otherwise stated, the size used in flashlights can be used in our experiments.

Procedures: PART A

1. Wrap about 40 turns of insulated wire around the bolt. Leave at least six inches of wire free at each end.
2. Connect one end of the wire to one of the terminals of the dry cell. Take the other end of the wire and hold it to the other terminal of the cell. A regular flashlight cell has two terminals, as do larger dry cells. The center post on the top of the cell is the positive (+) terminal and the bottom of the cell acts as the negative (—) terminal. The wire may be fastened to the bottom of the cell with Scotch tape, and the wire at the center post can be held safely with a finger.
3. Now try to pick up paper clips with either end of the bolt. It is safe to hold the bolt.
4. Remove the wire from the center post. Most of the paper clips will fall off immediately. The others will fall off as soon as the bolt loses enough of its magnetism.

Thus we see that for our electromagnet to work, we must provide a complete path for the electric current to flow in — that is, from battery to bolt, and back to



the battery. We call this a complete circuit.

A little warning about the use of dry cells: Do not allow the current to flow too long at one time. A warm wire indicates that a complete circuit has been formed for too long. Such a condition drains the energy from the dry cell. You might also be burned, but not seriously.

PART B

Count the number of paper clips you were able to pick up with one dry cell. Insert a second dry cell into the circuit in series, as indicated in the diagrams. Note that in series wiring, the positive terminal (center post) of one cell is connected to the negative terminal (bottom) of another.

Explanation: In Part A, when electricity from dry cells is allowed to pass around a soft iron bolt, the atoms within the bolt are all lined up in such fashion that all north poles point in one direction and all south poles in the opposite direction. This causes the bolt to be magnetic. The bolt loses most of its magnetism shortly

after the current is shut off. A magnet of this type is called an electromagnet.

In Part B, we observed that when another cell is placed in series in the circuit, the bolt becomes a stronger electromagnet. More electrons flow through the wires that surround the bolt, resulting in more lining up of the iron atoms.

We can prove for ourselves that the strength of an electromagnet can be increased by using more dry cells in series, or by winding more wire around the bolt. *We must keep this in mind when we perform some of the other experiments.*

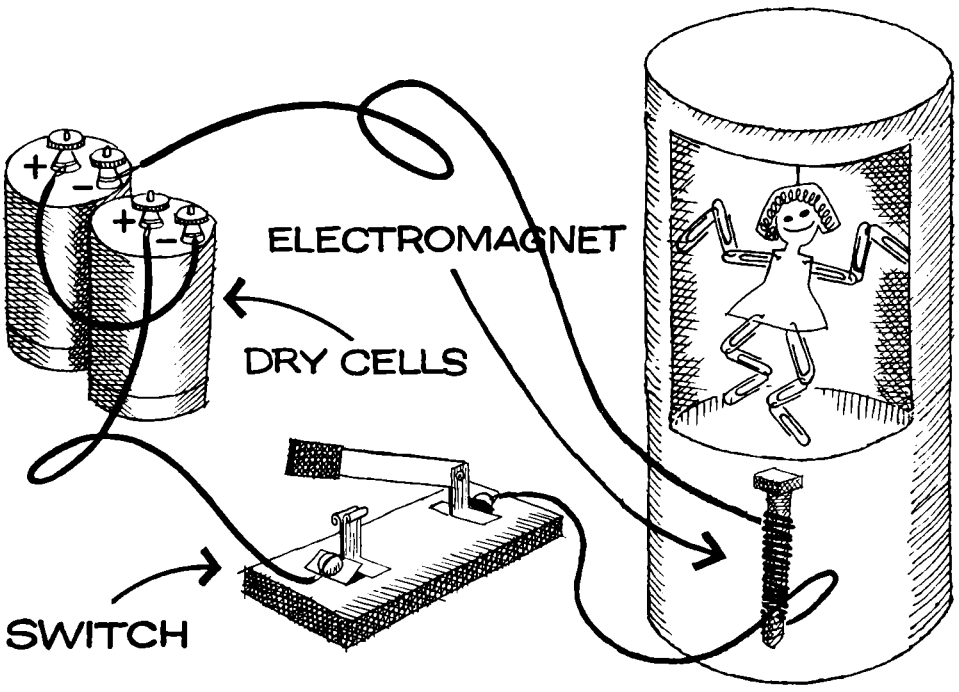
Experiment 62 A dancing doll

Here is one for the girls, but the boys will enjoy doing it even more than the girls. This one you can do as part of your main attraction during a puppet show. Here's all you do:

Materials: A large cylindrical cereal box, a 4″ x 6″ card, cardboard from a flat-sided cereal box, a dozen paper clips, a switch, 2 or 3 dry cells, and an electromagnet that you made in Experiment 61.

Procedures:

1. Cut out a figure of a doll using a piece of cardboard from a cereal box. The over-all length should be about five inches.
2. Make the arms and legs by stringing steel paper clips as shown in the diagram. It will be necessary for you



to experiment with the number of paper clips. You may, however, want to start with four clips for each arm and six for each leg.

3. Suspend the doll by means of a fine thread over a "stage" made from the cylindrical cereal box.

4. Place in the top of the cereal box the larger end of an electromagnet. Just the head of the electromagnet should stick up from the top of the box.

5. Connect two or more dry cells in series to the electromagnet. Connect a switch as indicated.

6. Place the switch out of sight of your visitors. Throw it on and off with either your foot or your hand. Observe how your doll enjoys dancing.

Explanation: The doll dances because the electromagnet attracts the paper clips when the current is on. When the circuit is broken, the clips are released and they move to their normal position. This change of motion gives the doll the appearance of dancing.

Experiment 63 A magnetic crane

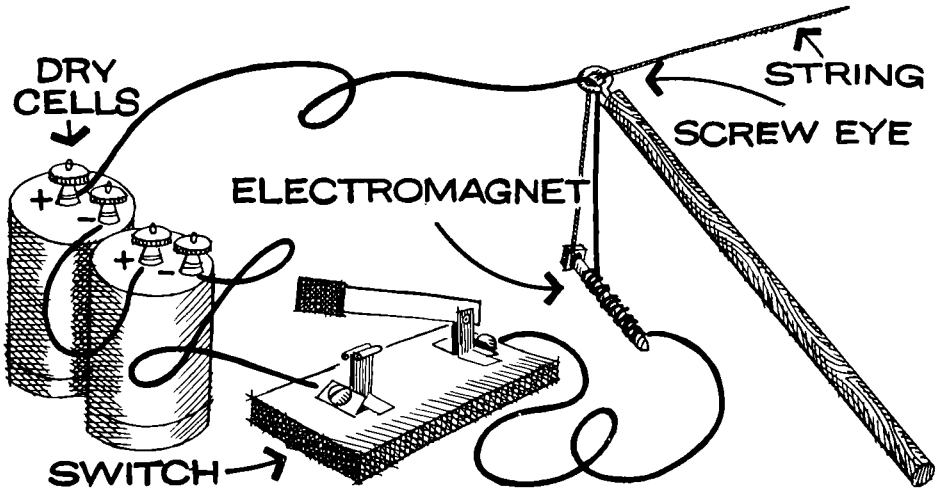
In ancient times man did all his work with his hands. Gradually he learned to use animals, tools, and machines to do some of his work. This help enabled him to accomplish tasks which would otherwise have been impossible. Machines have all but replaced animals as man's helpers in our rapidly advancing society. One such machine is the magnetic crane. This device can lift and transfer thousands of pounds of steel in a very short time and with great efficiency. This crane is also used to separate magnetic substances from nonmagnetic ones.

A magnetic crane makes use of many scientific principles that we have been using in this chapter. Let's make a model of this machine.

Materials: A switch, 2 dry cells, a dozen paper clips, an electromagnet, 3 feet of bell wire, 3 feet of string, and a yardstick or pointer with a small screw eye in one end.

Procedures:

1. Use the electromagnet you made in Experiment 61, or make one now for use in this experiment.
2. Connect the two dry cells in series as shown.
3. Connect one end of the wire from the electromagnet to one of the terminals on the dry cell, and connect the other end of the wire to one of the terminals on the switch. Then complete the wiring as shown in the diagram.



4. Tie a string to the nail and pass the other end through the screw eye in the yardstick.
5. Complete the circuit by pushing down on the switch.
6. Lower the "boom" — the electromagnet — over the iron objects you wish to move. With the switch in the "down" position, swing the boom with the load to the place where you want to drop the materials. Break the circuit by putting the switch in the "off" position. The iron substances will fall off the electromagnet.

Explanation: When the circuit is completed, the iron core (nail) acts as an electromagnet and as such attracts iron objects. When the circuit is broken, the iron core loses its magnetism, and the iron objects fall off. This process may be repeated many times.

Experiment 64 Making a simple telegraph

The last one hundred years of research have given us such improved means of communication as the telegraph, telephone, radio, and television. Through im-

provements in communication all the people of the world have become our neighbors.

In this experiment we shall learn how one of these methods of communication — the telegraph — works. A telegraph is a means of sending code messages with the aid of electricity. It was invented in 1835 by Samuel F. B. Morse after many years of experimentation. A few years later he built a telegraph with which he actually sent and received messages quickly over a long distance. His first message — "What hath God wrought?" — was tapped out on May 24, 1844, on a telegraph key in Washington, D.C., and was received in Baltimore, Maryland, about one six-thousandth of a second later.

A simple telegraph, such as we shall make, has three parts — a key, a sounder, and dry cells. The key and sounder are connected by insulated wires to one or more cells. When we press the key, electrons flow through the sounder and cause it to give long or short clicks. For a "dot," or short click, the key is held down for a very short time. The two clicks the sounder makes come close together. For a "dash," or long click, the key is held down for a longer time. The clicks are farther apart.

Modern telegraph offices have telegraph-typewriters that receive coded electric impulses for each letter of the alphabet so that they can automatically type the message directly onto a narrow band of paper.

Materials: Three pieces of wood (4″ x 8″, 4″ x 4″, and

2″ x 4″), 2 steel nails with large heads, several small nails, 2 dry cells, 20 feet of insulated bell wire, a large metal can, tin snips or old scissors, and Scotch tape.

Procedures:

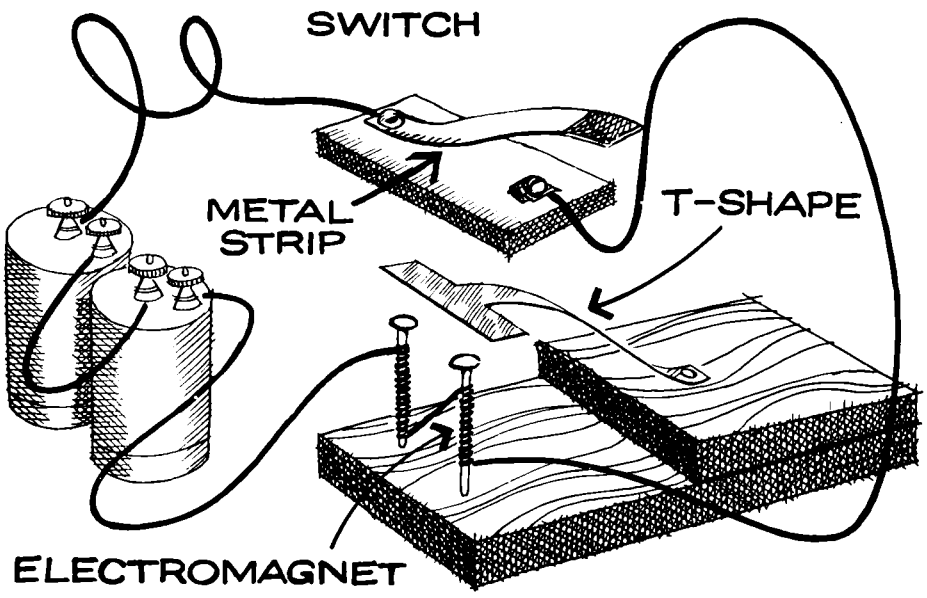
1. Nail the 4″ x 4″ board to one end of the 4″ x 8″ board so that the 4-inch sides are flush and the two boards make a step. Use small nails.
2. Drive the two large nails into the other end of the lower board, and wind the wire around the nails as shown in the diagram. The nails should be about two inches apart and have about 20 turns of wire around each. This is the electromagnet.

Directions for winding the wire. Leave about 1½ feet of wire and start winding at the top of the left nail. The winds should be very close to each other. Continue at the top of the right nail. There should be about two feet of wire left at this end for connections.

3. Cut a T-shaped piece from the metal can. The top of the T should be large enough to reach over the two nails. The telegraph is more sensitive if the lower part of the T is tapered.

Cut another piece, about 1″ x 4″, from the can. Use the 2″ x 4″ board and make a switch. See diagram on next page.

4. Nail the lower end of the T to the top board so that the top of the T rests on the heads of the two nails. Curve the 1″ x 4″ piece and nail one end on the 2″ x 4″ board. Place a nail at the other end for your second terminal.



5. Complete the construction of the telegraph by connecting the wires as indicated.
6. The telegraph is ready. Push down on the key and observe what happens to the T-shaped metal strip. Repeat several times. Should your results be unsatisfactory, check the wiring and the position of the T.
Explanation: The real telegraph works on the same principle as yours. The metal strip on the small board is the key that completes or breaks the circuit. The large board with the T is the receiver. When the circuit is completed, the current flows through the electromagnet, which then sets up a magnetic field which attracts the T-shaped piece of tin can and causes a click. When the circuit is broken, the electromagnet ceases to attract the T and it snaps back into place.

You can send messages to your friends by wiring two keys and two receivers.

Experiment 65 A motor from an oatmeal box top

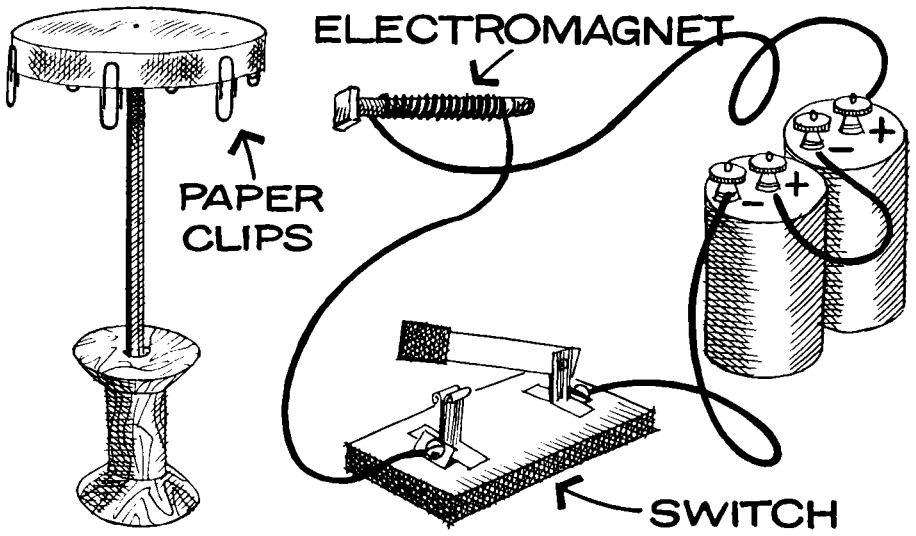
In this experiment we shall apply all of the ideas learned in the four preceding experiments.

Materials: The top of a cylindrical cereal box, a small spool, a needle, a snap fastener, a 3-inch bolt, 2 dry cells, a pencil with eraser, 3 feet of fine insulated wire, and 6 paper clips.

Procedures:

1. Make an electromagnet as described in Experiment 61.
2. Push the needle into the center of the eraser on the pencil. Place this in the spool with the needle sticking up.
3. With the aid of a ruler find the center of the box top and insert one part of the snap fastener through it. From the other side of the box top, snap the other part over the first part. Place the six paper clips around the rim of the box at equal distances from each other. Place the box top with the snap fastener on the needle, as shown in the diagram.
4. Bring one end of the electromagnet near one of the clips. Press down on the switch. As the paper clip approaches, take your finger off the switch. When the clip has passed by, press the switch again to attract the next clip. Repeat at such a rate as to cause the box top to rotate constantly.

Explanation: The wire and the bolt serve as an electro-



magnet, the paper clips and the cover form the armature, and the dry cells supply the necessary current. When the switch completes the circuit, the bolt becomes an electromagnet. It attracts the paper clips. The attraction of the paper clips causes the box top to rotate. The continuous making and breaking of the circuit gives the box top sufficient momentum to keep it spinning.

Experiment 66 Making a real electric motor

This is one experiment you should do only if you have patience, time, and are willing to put into practice many of the ideas learned in previous experiments. Once you complete the experiment successfully, you'll not regret having spent the time doing it. You may want to make some changes that you believe will make the motor work better. Try some. There's nothing to lose. If your plans don't work, you can always go back

and carry out the procedures described here.

Materials: A piece of soft wood about 6″ x 4″ x ¾″, glass tubing about 1½ inches long (the glass portion of a medicine dropper will do), at least 4 dry cells, 4 nails each about 3 inches long, 2 thumbtacks, a switch (you can make this), a magnetic compass, a large cork (about 1½″ x 1″), a thin strip of copper or heavy aluminum foil ¼″ x 2″, and at least 5 feet of #22 insulated wire.

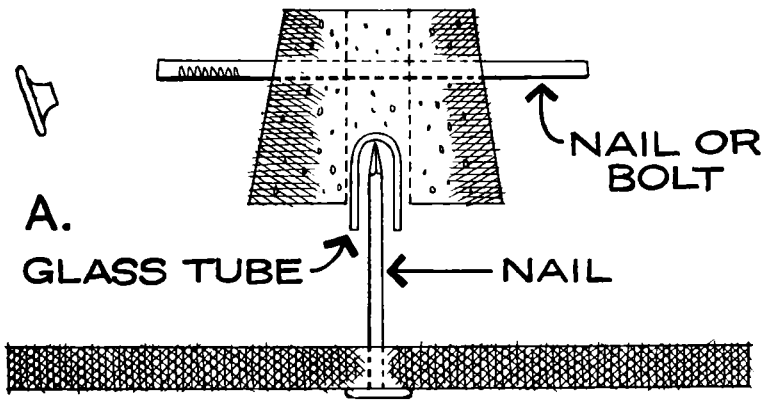
Procedures:

PART A. Making the frame and armature

1. Carefully drive one of the large nails up through the bottom of the board. See diagram A.

2. Seal one end of the medicine dropper or glass tubing over a gas flame. An alcohol or candle flame is not hot enough to do this. This tube should be about 1½″ long and wide enough to fit over the sharp end of the nail in diagram A.

3. Drill a hole through the cork. The hole should be the right size to make the tube fit snuggly. If you should make it too large, you can always add a little glue or wrap a piece of cloth over the tube. The tube *must* fit tightly in the cork. See the diagram.



4. Through the upper portion of the cork drill a hole a bit smaller than one of the large nails. With a hack saw, cut off the head and point of the three-inch nail. Moisten the nail, and carefully drive it through this hole. HINT: In place of the nail you may want to use a bolt with a nut. This will improve your motor.

5. Start near the cork and wind at least 20 turns of #22 wire around the nail to within one quarter of an inch from the end of the nail. Wind back and forth but always in the same direction — clockwise. Loop around the cork and wind the wire around the other end of the nail in the same way. Cut the wire, leaving at least six inches at each end.

6. Test the armature by connecting a dry cell to the ends of the wire. The ends of the nail should pick up paper clips when the circuit is completed. Pull the wires through the hole in the center of the cork. Now push the tube about halfway up the cork.

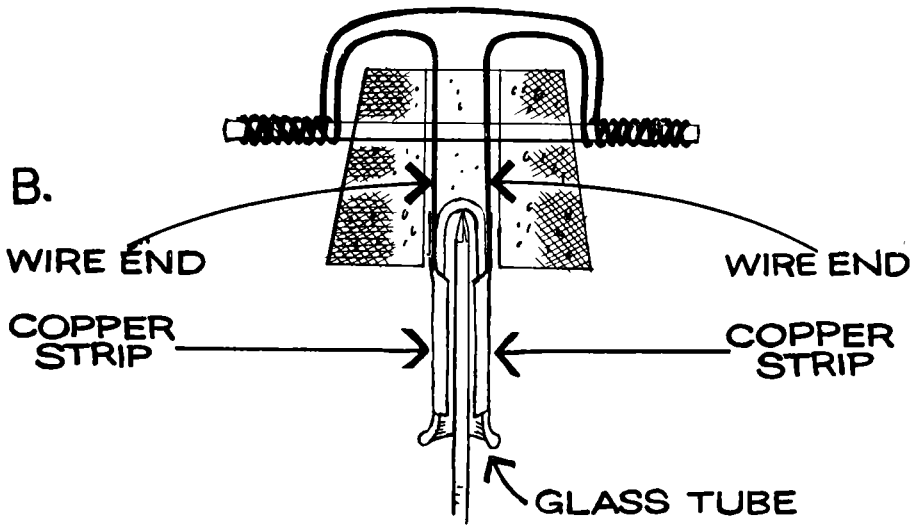
7. Balance the armature by pivoting it on the nail, as shown in diagram A. It must spin evenly and freely.

PART B. Making the commutator

8. Cut two strips of copper and insert them between the glass tubing and the cork. See diagram B. Be sure the two strips do not touch each other.

9. Next, insert one of the ends of the armature wire between the glass and one metal strip. Do likewise with the other end of the armature wire and the other metal strip. The two metal strips are the commutator.

10. Again, balance it on the nail.

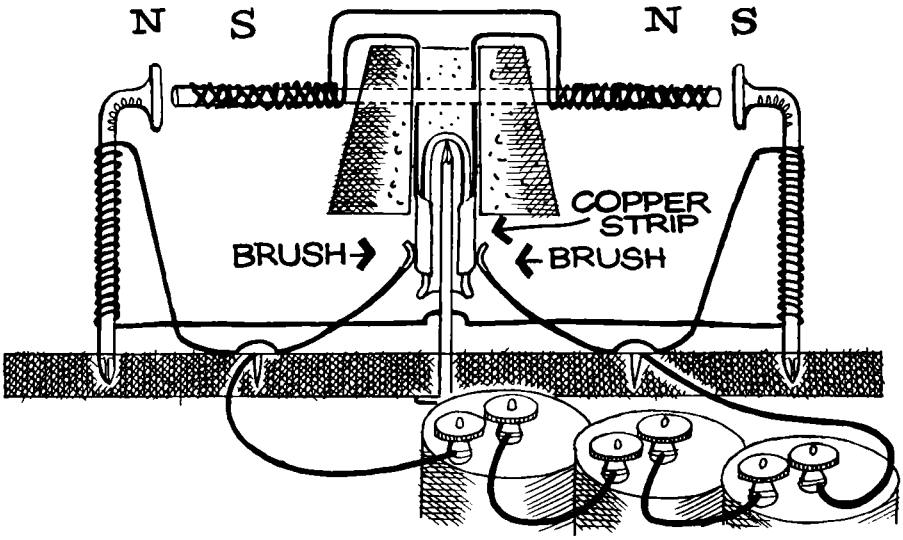


PART C. Making the field magnet

11. With the use of a vise and a hammer or pliers, bend the heads on the other two nails at a right angle, as shown in the diagrams on the following pages. Drive the nails into the board. The nail in the armature should come close to the heads of these two nails. Also, the horizontal nail should be level with the heads of these nails. These two steps are very important.

12. Wind about 40 turns of #22 wire around the first nail. Then lead the wire along the base and wind an equal amount of wire on the other nail. Attach the ends of the wire to two thumbtacks on the base as illustrated.

13. Connect the dry cells to the tacks. Test to see whether or not the north pole of the compass needle is attracted to one nail, and the south pole to the other nail. If this is not the case, rewind one nail so that the wire goes around it in the opposite direction. We can change the poles of a magnet by changing the direction in which the current flows around the core or nail.



PART D. Making the brushes

14. Cut two pieces of wire about 6 inches long. Scrape the insulation off the ends.

15. Fasten the one end of one piece to the thumbtack and adjust the other end so that it brushes against the commutator. Fasten the other wire to the other thumbtack and the other part of the commutator.

16. Complete the wiring of the dry cells in series.

17. Start your motor by giving the armature a little push. It may be necessary to adjust the motor by twisting the brushes or the commutator. The armature should revolve with considerable speed.

Explanation: Our electric motor has five essential parts:

1. The cork with the horizontal nail and wire wrapping is called the *armature*. It is an electromagnet. The magnetic poles at the ends of the nail change with each complete rotation of the armature.

2. The *commutator* is that part where the two wires

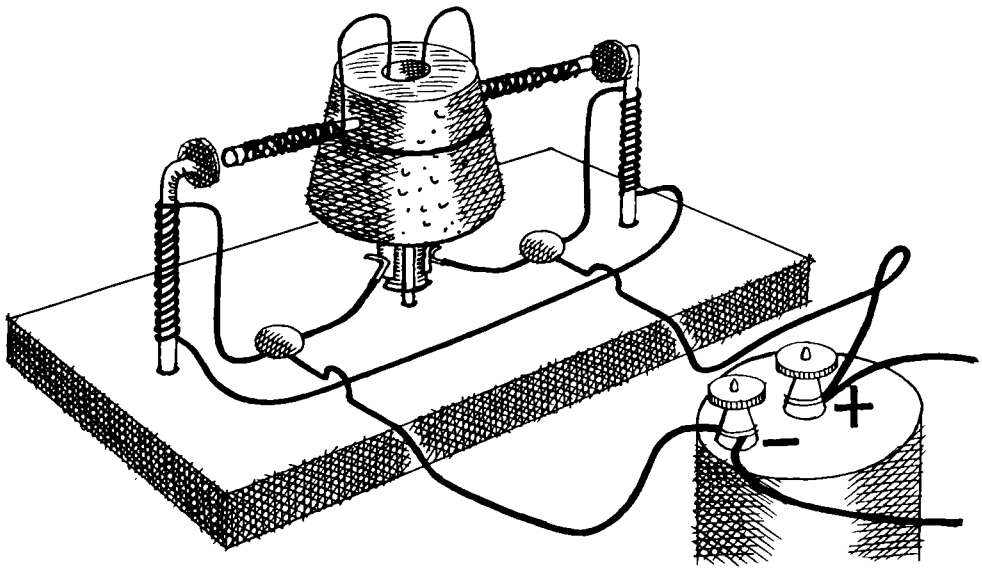
from the armature come in contact with the two copper strips. A commutator changes the direction of the flow of electricity in the armature.

3. The *brushes* are the wires that carry the current from the dry cells to the two parts of the commutator.

4. The two *field magnets* are the two nails that make it possible for the armature to spin. The top of one of the nails must be an S pole, and the top of the other nail must be an N pole. These poles remain the same while the motor is operating.

5. The dry cells supply the *source of power.*

With these parts in mind, let us trace the flow of current through the various parts to see what makes the motor work. Let's do this a step at a time.



Step 1: With the switch down, the current flows from the dry cells, to the brushes, to the commutator, to the armature, and also through the two field magnets, and back to the dry cells.

Step 2: Spin the armature slowly by hand. Notice that each brush touches first one metal strip, then the other. This results in a change of direction in the current flowing through the armature — first from + and then from —. As the direction of the current changes, each end of the armature will change from one pole to the other. The end with the N pole will become an S pole, and so forth.

Step 3: The armature starts rotating of its own accord when the current is on because its poles are attracted to the poles of the field magnets — unlikes attract. If nothing else happened, the motor would come to a complete standstill after this small rotation of the armature. Just before the unlike poles reach each other, however, the direction of the flow of current in the armature is changed by the commutator. This change reverses the poles in the horizontal nail, and we have like poles near each other. The result is repulsion — likes repel. It may be said that an electric motor works because of attraction and repulsion between the field magnets and the armature.

The above explanation is challenging, and it may be necessary for you to go through it several times.

10

ATOMIC ENERGY

WE HAVE been hearing and reading a great deal about atomic energy ever since 1954. In that year, atomic energy was used for the first time to propel a powerful submarine, the *Nautilus*. Since then, atomic energy has been used in other submarines, in large ocean vessels, and in the making of electric energy. We know the atomic-energy age is here to stay. But what is atomic energy? Let us study it by looking at a small atomic-energy machine we have in our home. This "machine" is any watch or clock that has a luminous dial. The numerals and hands on such a dial glow at night because they are painted with radium and other chemicals.

Radium, like the other elements, is composed of atoms. Radium atoms, however, behave differently from the atoms of most other elements. Madame Curie and other scientists found that atoms of radium give off invisible rays. When these rays bombard the atoms of other elements, they cause these atoms to give off heat and light. The energy of the radium rays is a form of atomic energy. The amount of atomic energy given off by a luminous dial is extremely small. We can, nevertheless, see the results of such fast-moving rays.

Try this. Take a clock with a luminous dial into a

dark room. Give your eyes a chance to become accustomed to the darkness by staring into the darkness for more than one minute. Look at the numbers and hands on the dial with a magnifying glass. What you see are really millions of small flashes of light. The flashes are so fast and so close together that they make one continuous glow of light. Remember, the flashes we see are not the radium rays but rather the after-effects produced when the rays strike other atoms. The rays usually strike zinc sulfide, which is incorporated with the radium.

Atom splitting

Scientists like Albert Einstein knew that inside each atom is stored an enormous amount of energy. They did not know how to release this energy until Ernest Rutherford, an English scientist, made important discoveries in 1919. He and other scientists realized that in order to release the energy locked up in the atom, its nucleus had to be bombarded by atomic "bullets." Rutherford used alpha particles as atomic bullets, and other scientists used neutrons. Neutrons, as we have learned before, are found in the nucleus of an atom and have no electric charge. They do have strong penetrating power, however, and can go through the electron area of atoms and into the nucleus itself. When a collision occurs, the nucleus may capture the neutron. As a result, the atom may be split and terrific amounts of energy released in the form of heat and dangerous rays.

In atom-splitting machines, which are called reactors, uranium-235 and plutonium are commonly used. When atomic bullets hit uranium-235, the atom may be split in two, forming different elements called krypton and barium. The neutrons released during the splitting of atoms may cause several additional atoms to split and release neutrons. This continues until a very large number of atoms are being split almost simultaneously. This build-up of neutrons and atom splitting is called a chain reaction. It is as if you ignited a box of matches all together. One match would ignite another; these two would ignite at least two more, and so forth. Soon the burning matches would liberate enough energy in the form of heat and light to ignite all of the matches.

It has been estimated that a quantity of uranium the size of the letter *o* contains sufficient atomic energy to propel an airplane around the earth a distance of 25,000 miles.

Atomic plant

Since atomic energy is so powerful and at the same time so dangerous, how can it be used safely? This is an excellent question. Scientists have made great progress in enabling us to use atomic energy safely for peacetime purposes.

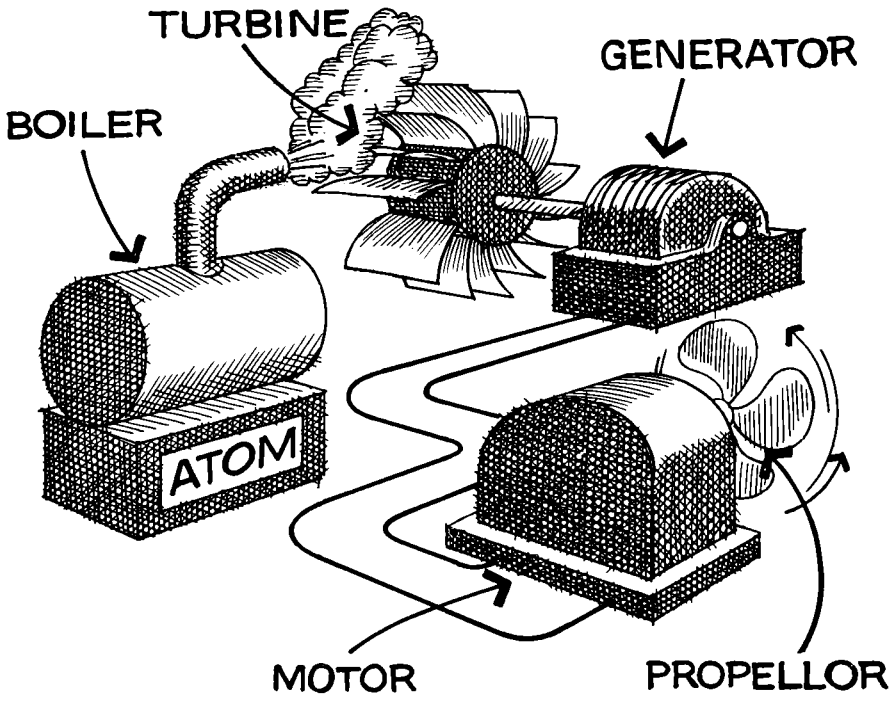
In the first place, the rate at which atoms are split in a reactor or atomic furnace can be controlled. This is done by moving rods in and out of the reactor. These rods are usually made of graphite or carbon. When the rods are in the atomic furnace, they absorb some of the

neutrons liberated by an atomic decomposition. This slows down the chain reaction, for now there are fewer atomic bullets to bombard other atoms. To speed up the reaction, the rods are raised and fewer neutrons are captured by the graphite.

Reactors are safe and are being made safer through continuous research. Scientists have found that when radioactive substances are enclosed by walls made of thick, heavy materials, such as concrete or lead, experiments can be carried on with a high degree of safety to the workers.

Changing atomic energy into useful energy

Let us now consider how atomic energy is used to propel a submarine or to make electricity. In the diagram below, ATOM is the atomic furnace. It is here, as we said before, that uranium atoms are split and large



amounts of heat energy are released. This heat is used to convert water into steam in the boiler. The outer parts of the boiler and its pipes are lined with heavy lead. From the boiler, the steam goes to a turbine where it turns the turbine blades. The turbine shaft is connected to a generator that produces electricity. The electricity energizes a motor which turns the propeller shaft in a submarine or an ocean liner.

In general, this method used to make electricity or propel a submarine is not very different from that used in non-atomic plants. The big difference is in the fuel that heats the water and turns it into steam.

Let us now perform a few experiments that will help us to understand a little better this fascinating topic of atomic energy.

Experiment 67 Models of atoms

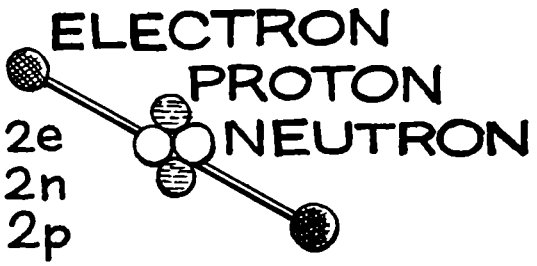
Just how does this atom look that we have been talking about? Scientists do not know the exact answer to this question. They do, however, have ideas, and they have good reasons for believing their ideas are correct. Scientists call their explanations of these reasons *theories*. The atomic theory helps us to understand the structure of the atom.

Materials: Toothpicks, modeling clay, airplane cement, and some ball-shaped cereal. (If you don't have modeling clay, you may want to use gumdrops of different colors.)

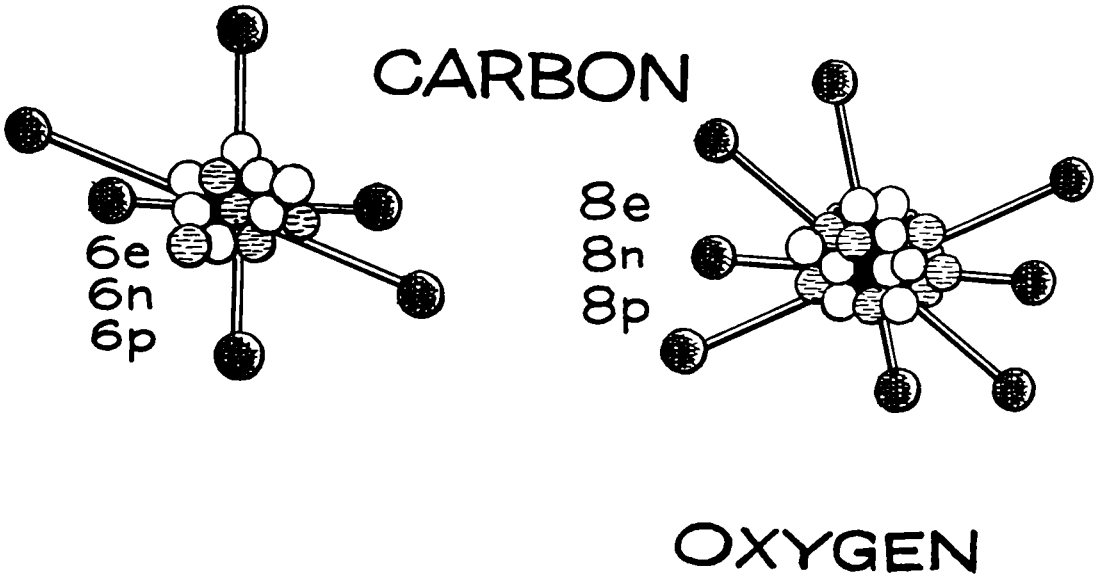
Procedures:

1. Take three different colors of modeling clay. Make balls the size of a marble from these clays. The number you need depends on the atom you desire to model.
2. For a helium atom, take two red and two green balls and put them together as shown below to represent the nucleus. Let the red stand for protons and the green for neutrons. Insert two toothpicks into the nucleus. Attach an electron of a third color at the extended ends of the toothpicks. You may want to use cereal, or gumdrops of different colors, instead of clay balls for the electrons.
3. Attach the whole atom to a stand made of clay or wood.
4. Make other atoms as indicated below.

Explanation: The round balls at the center, to which the toothpicks are attached, make up the heaviest part of the atom — the nucleus. It is here that almost all of the atom's energy is concentrated. In order to split the nucleus of an atom, the atomic bullets must travel at a very high speed to get past the electrons. Remember,



HELIUM



the electrons are also moving at a very high speed around the nucleus.

To construct a model of uranium-235, you would need 92 balls to represent protons, 143 for neutrons, and 92 for electrons. The model will suggest a reason for using uranium-235 in reactors. It has 143 neutrons to act as atomic bullets. The nucleus of U-235 can capture neutrons, split, and release other neutrons as well as energy.

Experiment 68 Chain reaction

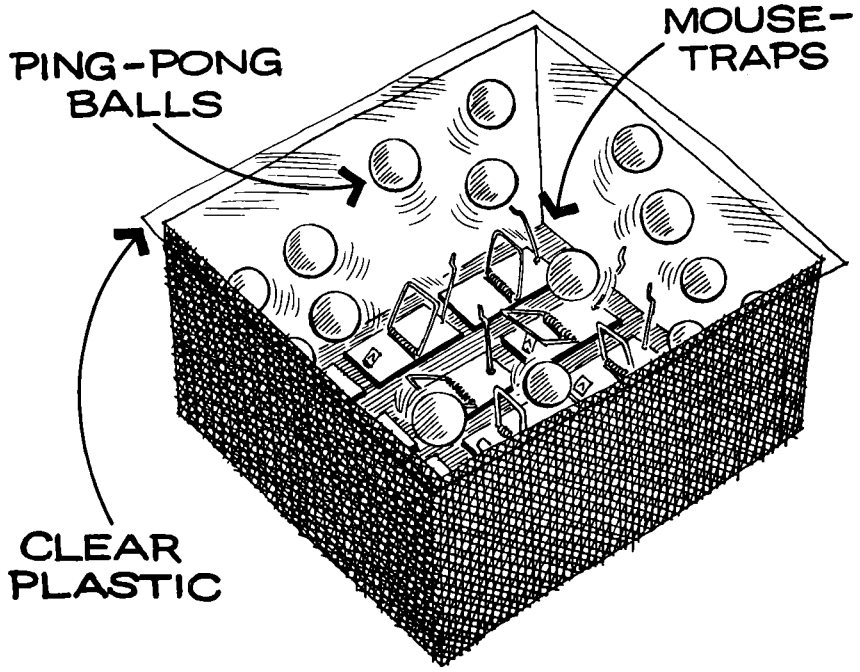
Do you know that you set off chain reactions many times? As a matter of fact, you probably did so before you were able to walk. Each time you built a tower with blocks and then knocked it down, you set off a chain reaction. Each time you lined up dominoes and then made them fall by flipping one, you set off a chain reaction.

Materials: Mousetraps and ping-pong balls.

Procedures:

1. Carefully set six or more mousetraps in a large cardboard box. Assume that each trap represents an atom of uranium-235 with stored energy in the nucleus.
2. Place two ping-pong balls opposite the trigger of each trap. These balls represent the neutrons.
3. Place a sheet of clear plastic over the top of the box. It must be taut. Work your hand into the box so that you can drop a ping-pong ball on one of the triggers. This represents an atomic bullet that starts a chain reaction.
4. Can you imagine what this would be like with 143 mousetraps and ping-pong balls going off simultaneously? With trillions going off all at once?

Explanation: When an atomic bullet strikes the nucleus of an atom and the nucleus splits, an enormous amount of energy is released in the form of heat and light. This



reaction is very rapid, as indicated by the setting off of the traps. When the products of one reaction set off others and these set off additional ones, we call the process a chain reaction.

Experiment 69 Controlled and uncontrolled chain reactions

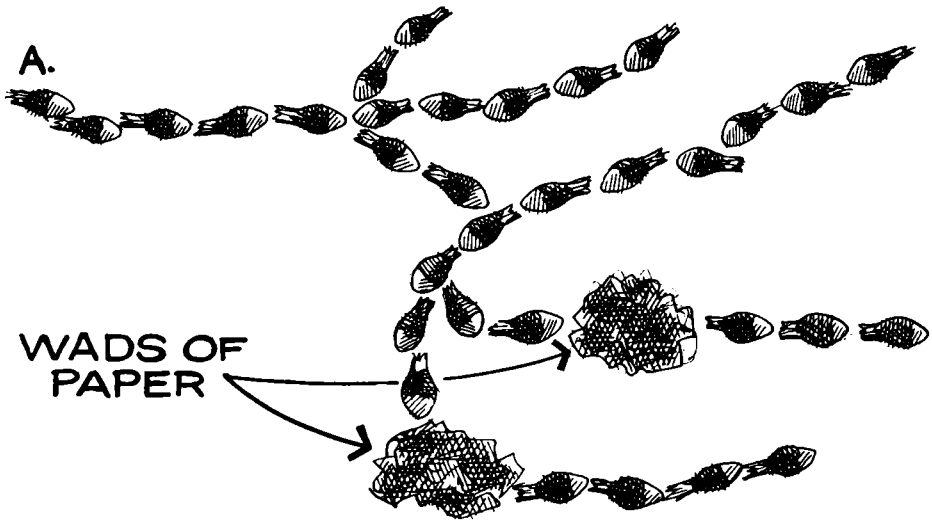
Our atomic reactors would be of practically no value if we were unable to control them. We can demonstrate the difference between a controlled and an uncontrolled reaction by performing this experiment.

Materials: A box of wooden matches, a sheet of asbestos or some other nonflammable material, and a small container of water as a safety precaution. You'll need a parent on hand before you attempt this one.

Procedures:

1. Break off the sticks of about a dozen matches — about ⅛ inch below the match head. Arrange the match heads as shown on the next page.
2. At certain points place pieces of wet paper. These are the special rods or absorbers of energy.
3. Light a match and place it at point *A* as shown in the diagram.
4. Observe what happens to the right and left sides of the arrangement.

Explanation: On the right-hand side of the arrangement, the matches ignite each other until the wet piece of paper is reached. The reaction on this side goes no



further. On the left-hand side, the reaction continues, for there is nothing to interfere with the burning.

As observed, the reaction starts slowly by first one match igniting, then two, then three, etc. The chain reaction at this point is uncontrolled. If this were a nuclear reaction, it would soon become too violent and might destroy the apparatus and even the building in which the reactor was housed. To prevent this from happening, it is necessary to control nuclear reactions by various means. One method is to use control rods. The wet paper serves as a control rod in the experiment using match heads.

Experiment 70 Constructing a radioactive-fallout meter

Madame Curie and her husband, discoverers of radium, and other investigators of radioactivity have used three basic instruments to study the presence of radio-

active particles. They've used the electroscope, the Geiger counter, and the cloud chamber.

What are radioactive particles? For our purpose, let's consider them to be powerful rays given off by radioactive materials such as radium, uranium, or plutonium. Scientists call the rays alpha, beta, and gamma, after the first three letters in the Greek alphabet. The gamma rays have the greatest penetrating power of the three and can pass through a plate of iron several inches thick. Gamma rays affect living tissues more than alpha or beta rays. The danger from radioactive substances is mainly from gamma radiation.

The instrument we shall make in this experiment resembles the electroscope more than the other two. Ours will not tell us the kind of rays, but if constructed very carefully, it will indicate the presence of radioactive particles and *roughly* the amount of radiation in the atmosphere. The instruments used to give very accurate results cost anywhere from a hundred to several thousands of dollars. Ours will cost a few cents at the most.

Materials: A clear 10-oz. drinking glass about 6″ tall, the metal lid from a can to fit the top of the glass, a 12″ x 12″ piece of regular aluminum foil, cellulose tape, *white nylon* thread, a long black comb, a hammer, a 25-cent piece, scissors, a table knife, a yardstick, and a razor blade.

Procedures:

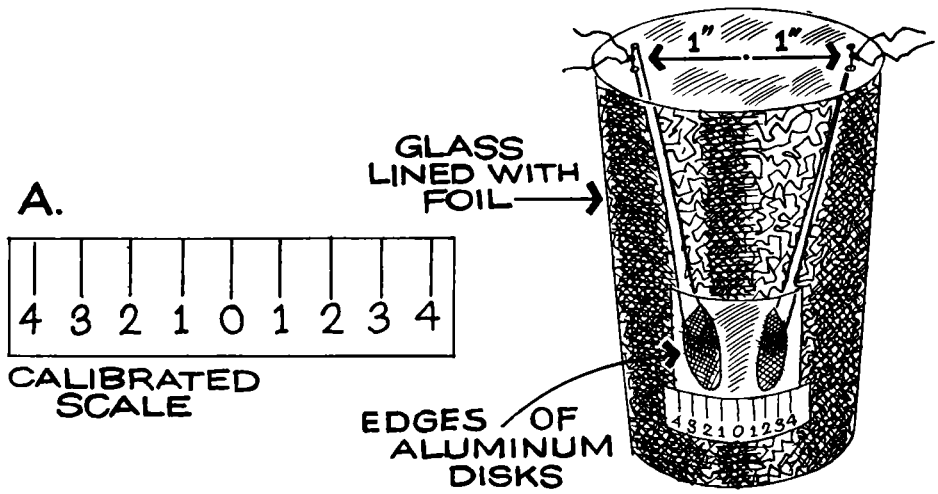
1. Roll the sheet of aluminum foil inside the glass. Be sure the sides and the bottom are *completely* covered.

2. Carefully cut out a one-inch square opening in the foil starting about three inches from the top of the glass. Cut another directly opposite this opening. When the glass is held at eye level, you should be able to see through the two windows. Use the razor blade to make the windows. See diagram A.

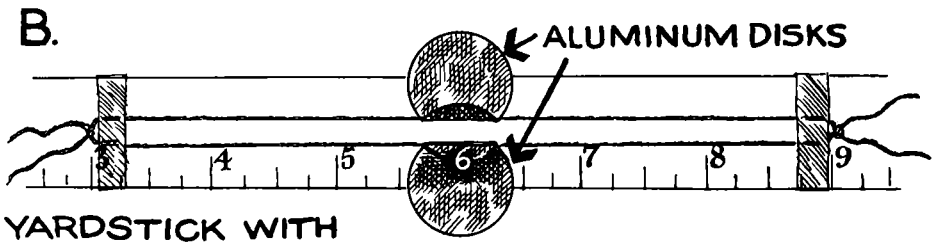
3. Mold the foil inside the glass with your fingers and the handle of the knife. Be sure not to tear the foil. The foil must make *contact* with the inside walls and the bottom of the glass.

4. Duplicate the calibrated scale shown in the diagram on a piece of paper and fasten it with tape to the outside of the glass just below one of the windows.

5. Take the metal lid and with hammer and nail punch two small holes close together about one inch from the center. Directly opposite these two holes and about one inch from the center punch two more holes close to each other.



6. Using a quarter as a pattern, cut out two circles of aluminum foil.
7. Cut two lengths of nylon thread, each about 15 inches long. Handle only the ends of the threads. Too much handling will result in the thread absorbing moisture and body oils. This will decrease the efficiency of the fallout meter. See diagram B.
8. Place the threads on the yardstick. They should be very close to each other but not touching — about ¼ inch apart. Measure off a distance of three inches from the middle. Tape the threads down at the two points. Make the threads taut. See diagram B.
9. Insert a knife under one thread at the 6-inch point. Slip one of the aluminum circles under the thread. Remove the knife, allowing the thread to fall on the disk. Fold not more than ½ inch of the disk over the thread. Rub the knife over this to make a good contact. Repeat with the other disk and thread.
10. Tie the two parallel threads together at each end and pull both knots down tightly to the tape. Make double knots. See diagram on next page.
11. Insert one set of the loose ends of thread through one set of the holes in the metal disk. Pull the threads up as far as they will go and tie them down on top of the lid. Remove the tape from the ruler at this end. Repeat with the other set of loose ends.
12. Raise the lid. You should have two aluminum disks hanging freely from the thread. It may be necessary to



YARDSTICK WITH THREADS AND DISKS IN PLACE

adjust the disks so that they face each other at the bottom of the loops.

13. Take a comb and charge it with static electricity, either by rubbing it with wool or by passing it through your hair. Bring the end of the comb in contact with each aluminum disk. Repeat this procedure until the like charges of static electricity separate the disks about ½ inch. Remember that it is difficult to obtain adequate static charges on a humid day.

14. Carefully place the lid on top of the aluminum-lined glass. The disks are not to touch the inside of the glass. Next, turn the lid about until you see the *edges* and not the sides of the disks when you view them through the window in the aluminum lining.

15. Look through the window from a distance of about one foot. Move the lid until each disk edge points to the same number on both sides of the scale.

WORKING THE METER.

Determine the number of seconds it takes the bottom edges of the disks to move toward each other over one full number on both sides of the scale. *The slower the*

rate at which the disks come together, the lower is the amount of radiation in the atmosphere. We must keep in mind that they will eventually come toward the zero point, even though there may be very little radiation, owing to the movement of air, which carries heat and other forms of energy. Scientists refer to this as "natural leak."

It is possible to show that the greater the radiation, the faster the disks come together by placing a watch with a luminous dial inside the glass. The disks, at the time they are placed in the glass, are charged. As radioactive particles leave the luminous dial, they make it possible for the charges to leak off the disks, and thus they become neutral. The result is that they come together. The watch is placed inside because the particles given off by the luminous paint are not very powerful, and we want to utilize all of the particles.

Try this: In your notebook keep a record over a number of hours or days to find out whether or not there is more radiation on some days than on others. Do this also after heavy rains or snowfalls.

Let's conclude this experiment by stating that through the use of this meter we can tell *roughly* the degree at which radiation is bombarding us, and whether or not we are being bombarded more today than yesterday or the day before.